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A TREATISE

ON

FORTIFICATION,

DEDUCED FROM ESTABLISHED PRINCIPLES,

WITH OBSERVATIONS ON THE

INCREASED EFFECTS OF ARTILLERY;

COMPILED BY

HECTOR STRAITH, CAPTAIN, H. P.

ASSISTANT IN THE FORTIFICATION DEPARTMENT, AND INSTRUCTOR
IN PRACTICAL ENGINEERING AND ARTILLERY,

AT THE

HON. EAST INDIA COMPANY'S MILITARY SEMINARY, ADDISCOMBE.

CROYDON:
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1833.

730.

DEDICATION.

TO

THE HONOURABLE THE CHAIRMAN,
THE DEPUTY CHAIRMAN,
AND
THE COURT OF DIRECTORS,
OF THE EAST INDIA COMPANY,

THIS TREATISE ON FORTIFICATION,

COMPILED FOR THE USE OF THE CADETS OF THEIR MILITARY SEMINARY,

IS RESPECTFULLY DEDICATED
BY THEIR MOST OBEDIENT,
HUMBLE SERVANT,
HECTOR STRAITH.

ADDISCOMBE,
April, 1833.

PREFACE.

> "I am very sensible, that it is not so much for a person's reputation, thus to make use of other men's labours, and that it is in a manner renouncing the name and quality of author. But I am not fond of that title; and shall be extremely well pleased, and think myself very happy, if I can but deserve the name of a good compiler."
>
> Rollin.

INTRODUCTION.

The compiler, having long felt in common with his pupils, the inconvenience of having to refer to a mass of French authors on the subject of fortification, has been permitted by the Hon. East India Company to prepare this treatise for the use of the cadets of their military seminary: and he has to thank Colonel Sir Alexander Dickson, K. C. B. and K. C. H., &c. of the royal artillery, the public examiner and superintendent of the studies, and Colonel Houstoun, C. B., the Lieutenant Governor, of the East India Company's military seminary; for the kind and handsome manner in which they have been pleased to recommend to the Hon. the Court of Directors the compilation of such a treatise.

For the matter contained in the following pages, he is indebted to a series of eminent engineers, both English and French; more especially to Colonel Sir John Jones, Bart. C. B. Royal Engineers, from whose standard works he has quoted liberally; to Colonel Pasley, C. B. of the Royal Engineers; to Colonel Napier, C. B.; to Colonel D'Aguilar's translation of the Military Maxims of Napoleon; to Mr. Landmann's work on mines; also to Major Reid, of the Royal Engineers; of whose translation of two French pamphlets, one on the Defence of Fortresses, and another on the Defence of Villages, the compiler has taken the liberty to avail himself; from being unable to procure these original documents published by the

Minister at War in Paris, in the years 1813 and 1814. The French authors whom he has consulted, are Vauban, St. Paul, Cormontaingne, Bousmard, Dufour, Guy de Vernon, Mandar, Baron Jomini, Villeneuve, &c.

The Atlas, in most cases, presents a mere outline of what the students should fill up carefully in detail and by scale, under the eye of their master; and instead of the beaten track of plates that formerly made the chief part of instruction in our military schools, would not the ingenuity and knowledge of the pupils be more called into action by requiring the execution, not only of a regular course of plates, some in outline, some partially, and others wholly filled up in detail, but also by demanding from them (according to their respective progress, abilities, and deficiencies), various details of works, differing from each other? For no instructor, who has had numbers passing rapidly through his hands, can have failed to be grieved with the propensity that pupils have to copy from each other, to hang on each other's resources, and thus to cramp their energies. In the higher branches of the art, the pupil will assuredly be much benefited by having plans of existing fortresses to attack; to have to calculate all the engineer and artillery *materiel* necessary for their sieges; to give them various features of ground on which to construct advanced works, bridge heads, entrenched positions, &c.; to defend and attack by mining in soils of a stiff and of a sandy nature; and by these and other means to call forth their theoretical knowledge at the same time that their skill in plan drawing is exercised.

The compiler is far from underrating the drawing of plans in all their beautiful detail, but he cannot refrain from remarking, that his own experience, both as a cadet and as a teacher, has taught him that the execution of plans should be grounded on a theoretical knowledge of the subject. The execution of any work in the field requires that it should be thoroughly understood by the directing officers, for which purpose, perfect plans must be prepared. To direct physical power, moral science is necessary: in the technical words of a modern writer,* "Physical science is the tool to *work with*, moral science is the drawing to *work by*," the tool is the soldiery, the drawing their officers.

The appendix, on the pressure of earth against revêtement walls, has been supplied by Samuel Parlour, Esq., one of the instructors in the mathematical department at the East India Company's military seminary: and the compiler is glad to have this opportunity of thanking Mr. Parlour for this valuable contribution.

On the subject of defilement, or the proper arrangement of works to neutralize the effects of commanding heights, the compiler has wandered out of the track followed by the most approved masters of the art; but he begs to remark that, in the seven years' experience he has had of teaching, he has never been able to convey to a class of thirty cadets, the instructions laid down on this important head by St. Paul, Bousmard, Dufour, &c.; and, as the demands of the public service for officers has always deprived him of his classes when arrived at the most advanced portions of their study, he has been forced to adopt the mode of instruction on defilement, laid down at the end of this volume. It is scarcely necessary to remark, that he does not dispute the accuracy and superiority of the directions of the eminent authors above named: but he conceives that the scientific intricacies of Bousmard on this head, are more calculated for such cadets as have passed from under their usual school courses: this observation, indeed, extends, in a great degree, to the whole of this work; as it will be perceived at once by experienced engineers, that many of the intricate and most delicate portions of the art, are left untouched.

It is impossible to divest any science of technicalities; things must have names, and the strange sounds of these sometimes tend to embarrass the learner; here, the greatest mass of technicalities are thrown into the definitions at the beginning of the work, and the compiler recommends that a thorough knowledge of them be acquired, as a pioneer to clear the way to the subject matter of the art: however, it has been his endeavour to disengage it from those unnecessary technicalities and sounding phrases with which it has been too long encumbered; and to lead the attention of the pupil to the principles established by the great masters of the art.

---

* Mechanics' Magazine, No. 491, page 233.

With the exception of the definitions being more full, and embracing more matter than has usually been given in such preliminary observations, the general arrangement of the work will not be found to differ materially from the usual course pursued by elementary writers on fortification.

The measurements are given in toises, yards, feet, and inches: the toise, as six feet: and the yard, as half a toise, or three feet. The toise is indeed a fraction more than two yards, or six feet, but as it has been hitherto generally treated as six feet, the compiler has thought it best to adhere to established custom.

After studying the first five chapters, and drawing clear detailed plans and profiles of the first system of Vauban, the pupil will benefit by going at once to chapter 10, and proceeding carefully through the attack. This will enable him the better to understand chapters 6, 7, 8, and 9, that treat on the various means of increasing the strength of fortresses by retrenchments, advanced works, casemates, mines, &c., and to form just opinions of their respective values.

ADDISCOMBE, April, 1833.

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THE READER IS REQUESTED TO CORRECT THE FOLLOWING

ERRATA.

Page 9—line 8 from the top, for "(see fig. 1, 20, 14, *r*, *m*, *n*);" *read* "see fig. 1; (20, 14, *r*, *m*, *n*)."

27—line 16 from the top, for "paragraph 22" *read* "paragraph 23."

28—line 14 from the top, for "of bastion," *read* "of the bastions."

29—line 20 from the top, for "(app. No. 3)" *read* "paragraph 352."

50—line 19 from the top, for "8, 8" *read* "18, 18."

63—line 19 from the top, for "faces, of the bastions," *read* "faces of the bastions."

72—line 3 from the bottom, for "definition 6," *read* "paragraph 6."

77—line 13 from the top, for "which assailants," *read* "which the assailants."

93—line 12 from the top, for "*double tenaillons*" read "*demi-tenaillons*."

96—line 16 from the top, for "horn works," *read* "horn work."

115—line 3 from the bottom, for "should he" *read* "should be."

130—line 1 of the note, for "to appendix, No. 1," *read* "to the appendix."

147—line 13 from the bottom, for "early 1814," *read* "early in 1814."

152—line 3 from the bottom, for "references," *read* "reference."

168—line 1, for "*Mowsé*" read "*Mousé*."

168—line 5 from the top, for "constructed, or a front," *read* "constructed on a front."

175—line 7 from the top, for "$\frac{U^1}{\delta}$. Now" *read* "$\frac{U^1}{\delta}$ (when the funnel is considered as the frustrum of a cone). Now."

183—line 7 from the bottom, for "house" *read* "hose."

235—bottom line, for "play" *read* "splay."

239—line 3 from the top, for "they selected" *read* "selected."

263—bottom line, for "four or five hundred 24-pounders" *read* "four or five 24-pounders."

292—line 17 from the top, for "battillons" *read* "battalions."

343—line 5 from the bottom, for "to direct faces upon the ground" *read* "to direct the faces upon ground."

354—line 12 from the top, for "*Abbattis*," read "*Abattis*."

385—line 14 from the top, for "breadth" *read* "breadths."

DEFINITIONS.

1. *FORTIFICATION* is the art of constructing military works, either for defensive or offensive purposes.

2. These works are of two kinds; viz. slight works for a temporary purpose; and substantial works for more durable purposes: the former is named "*field fortification,*" and the latter "*permanent fortification.*"

3. *Field fortification* has for its object, the protecting or retrenching of camps, villages, posts, passages of rivers, and the construction of such works as may be required to aid the operations of an army in the field.

The trenches and offensive works usually executed in carrying on a siege, come under the designation of field works.

4. *Permanent fortification* is the art of shutting in a piece of ground, or a city, of any form whatever, by defensive masses of earth and ditches, in a manner the most advantageous for making the greatest possible resistance, with a garrison proportioned to its size, against the attacks of superior numbers.

5. Every piece of ground to be fortified is supposed to be surrounded by a polygon, either regular or irregular, as the dotted lines, a, r, q, b, 4, 9, fig. 1; the lengths of the sides of which (as $a\,r$, $r\,q$, $q\,b$, &c.) are generally regulated by the necessity of the works being mutually within the range of the defensive weapons; this original imaginary enclosure (a, r, q, b, 4, 9) is called *the polygon of fortification.*

6. All the works constructed upon any one side of the polygon (as, for instance, all contained between the radii *Æ* 30 and *Æ* 40) is *a front of fortification.*

7. Should the polygon of fortification be quite regular, and the works on each front correspond with each other, it would be *a regular fortification.*

8. But should the polygon be irregular, having its sides and angles varying in dimensions, and the works differing on the several fronts, it would be *an irregular fortification.* Irregularity, however, does not imply weakness.

9. The outline or figure of a fortification is a succession of lines that form different angles with each other, (as *r*, *m*, *n*, *o*, *p*, *q*, &c. fig. 1), on the good arrangement of which much of the strength of the fortress depends: and as this arrangement may vary almost indefinitely, it follows that there are a great many *methods or systems of fortification.*

10. The succession of lines that show the figure of the fortification, and that indicate the directions in which the defensive masses of earth are laid out, is named the *outline or tracing;* and the general height to which these defensive masses are raised is termed *the relief.*

Two things are therefore to be considered in a fortress, the tracé and the relief: the tracé shows the manner in which the works should be laid out to obtain a proper defence; and the relief provides the requisite elevation for the artillery and musketry to ensure this defence.

11. The great mass of earth thrown up from the ditch inwards, in order to give the defenders a commanding surface for their cannon and musketry, is the *rampart* (as *a*, *b*, *c*, *h*, *t*, *m*, fig. 13); and the covering shot-proof mass of earth on the exterior edge of rampart is the *parapet* (as *k*, *f*, *g*, *h*, fig. 13): this parapet is usually seven feet and a half high, that it may cover the defenders behind it; and a step of earth is raised at the foot of its interior slope, sufficiently high to enable the defenders standing on it to fire over the crest of the parapet with ease; this step is *the banquette* (as c, *d*, *e*, *k*, fig. 13).

12. Immediately without the ditches of the place, there is a road of communication all round the fortress, usually thirty

feet wide; having on its exterior edge a covering mass of earth eight feet high, which slopes off gently towards the country: this road is *the covered-way*, and the sloping mass *the glacis*.

13. The first range of ramparts and parapets that enclose the place is *the body of the place* or *the enceinte;* and all the works between the enceinte and the covered-way are *outworks*.

14. *Advanced works* are such as are constructed beyond the covered-way and glacis, but within the range of the musketry of the main works.

15. *Detached works* are those which it sometimes becomes necessary to construct beyond the range of the defensive musketry of the main works; and, as a constant and steady communication with them cannot be kept up during a siege, they are consequently left chiefly to their own resources; nevertheless, they ought to exercise a general influence on the defence of the place.

16. In permanent fortification, the sides of ditches are supported by walls of masonry or *revêtements;* these walls are strengthened interiorly by buttresses at about fifteen or eighteen feet apart, called *counterforts*. The side of a ditch next to the place is the *escarp*, and that next to the country is the *counterscarp*.

The top of the revêtement is usually covered with a flat stone, to protect the masonry from being injured by rain; this stone projects about a foot beyond the rest of the masonry, and is called *the coping stone or cordon*.

In the actual construction of the works, the revêtement is first built, and the measurements of the other parts of the works are calculated and laid out from the cordon, which thus becomes a guiding line; and in the tracing is called *the magistral or master line*.

17. The general level of the ground upon which the works of a fortification are constructed is called the *plane of site*, whether it be horizontal, or oblique to the horizon, as on the general slope of a hill.

18. *A plane of defilement* is supposed to be a plane passing through the summit or crest of a work, and parallel to the plane of site.

19. If a plane pass through a work in any direction, the cut made by it is a *section:* if the cut be vertical and perpendicular to the face of the work, it is a *profile.* If horizontal at the base of the work, it is a *ground plan.*

20. The explanation of the term relief having been given in its fullest extent in definition 10, it now remains to point out its more limited signification; the total height of any single work, from the bottom of the ditch to the summit or crest of the work, is the *relief* of that work: for instance, in fig. 13, the height *a b* is forty-four feet and a half, which is the relief of this work.

21. The *command* of a work is its superior height over the work before it; or, in the case of there being no work before it, its height over the country.

Command is divided into command of fire and command of observation. In fig. 13, suppose the banquette of covered-way (*l*) to be manned by musketry, firing at an enemy's lodgment a little beyond the foot of the glacis (at *q*); then, if the crest of the work (*f*) in its rear has a sufficient elevation to enable it to carry its fire to the same spot (*q*), without any injury to the defenders on the covered-way (*l*), the work (*f*) is said to have a *command of fire* over the covered-way: but if the rear work be only high enough to look into the work before it, without both parties being able thus to carry their fire to the same point, the higher work has only a *command of observation* over the lower one.

22. Referring to definition 11, it is said that the guns are placed upon the surface of the rampart, covered in front by a parapet seven feet and a half high: now guns mounted on their carriages generally stand about two feet and a half or three feet from the ground; hence it becomes necessary to cut openings or *embrasures* through the parapet as in figs. 3 and 4, to permit the

guns to fire in the direction required; the height of the *sole* or bottom of the embrasure therefore depends upon the description of carriage on which the guns are mounted, usually two feet eight inches above the platform on which it stands; an embrasure is shaped as seen at *e e e* in figs. 3 and 4 (its *neck* twenty inches, and its *mouth* nine feet wide), that while the gunners who serve the gun may be as much covered as possible, the gun itself may have a certain extent of range right and left, by the *cheeks* or sides being thus made to splay outwards.

Guns in battery usually stand at eighteen feet apart, and the solid portion of the parapet between two embrasures is called *the merlon.*

The gun carriage rests and runs upon a *platform* eighteen feet in length; eight feet wide at the head and fourteen feet in the rear; the platform has also a rise of nine inches in the rear: this slope to the front is to lessen the recoil of the gun carriage, and to render it more easy to run the gun up into embrasure after being loaded.

At the head of the platform there is a beam of timber about six inches square, called *the hurter,* to check the wheels of the gun carriage and prevent them from injuring the interior slope of the parapet. Platforms are either of stone or timber, though more generally of the latter.

23. Guns in embrasure are evidently limited in their range to the size of the embrasure, and any attempt to widen this opening beyond the fixed dimensions would weaken the merlons to an unsafe degree. Therefore when guns are required to range freely over all the surface of the country before them, there is a platform of earth raised in rear of the parapet, of sufficient height and breadth to permit the guns placed on it to be run out over the crest of the parapet and to be pointed in any direction. Guns in this position are said to be "*en-barbette.*" In serving guns en-barbette, the gunners are exposed from the thighs upwards, and although this is a matter of less consequence while the enemy is beyond the range of musketry, and thus

cannot reach them with this weapon, yet when he has sufficiently advanced his attack, to lodge his riflemen in trenches within such a distance as to enable them to pick off the gunners; the guns must then be sunk into embrasure to protect the gunners as much as possible.

The garrison carriage upon which the gun rests, runs on four small wheels or trucks; and when thus mounted the gun is usually about two feet six inches from the ground. In order to raise it up, to enable it to fire over the crest of the parapet, there is a kind of frame work composed of two great sides or cheeks, upon which the carriage is placed, and on which its trucks run in grooves: by being thus elevated upon a *traversing platform*, the gun can fire over the crest of the parapet without the construction of the barbette mass spoken of in the first part of the definition: this platform has its name from traversing upon a pivot and trucks: for example, in fig. 52, there is a section, or side view, of one of the cheeks *c* of a traversing platform, upon the terre-pleine of the rampart: *p* represents a rest or block in which the pivot *r* works; *o* is a grooved plank laid circularly in the terre-pleine, in which the truck wheel *s* traverses, and by means of which, the platform *c* can be turned in any direction, and thus give the gun a great range right and left: it will be observed that the traversing platform *c* has a small rise to the rear, for the purpose mentioned in the last definition. While in the act of loading, the gunners upon the platform are exposed rather more than in embrasure, but in stepping down upon the terre-pleine, they are covered by the solid parapet.

The pivot, upon which the traversing platform turns, is not always fixed under the fore part, as stated above; but, in a round tower, it may be moved back to about *e*; then, *p* is made of a good large solid block with a groove in it (following the circular direction of the foot of the interior slope) in which the truck wheel *r* traverses in one direction, while *s* traverses, in its groove, in the opposite direction; the platform is thus turned on the pivot *e*, so as to point the gun in any direction: the situation of the pivot will therefore depend upon the purposes for which the gun is wanted, and the shape of the parapet behind which it is placed.

24. Referring to definition 11, and to fig. 13, the following are the names and general dimensions of a rampart and parapet.

The line *a*, *s*, *n*, *m*, *q*, is the plane of site, (definition 17): *a*, *b*, *h*, *m*, is the rampart: *k*, *f*, *g*, *k*, the parapet: *c*, *d*, *e*, *k*, the banquette. Let it be supposed, (in this fig. 13) that the relief *p r* is forty-four feet and a half; that is, that the depth of the ditch *o p* below the level of the ground is twenty-two feet; and the height of the rampart and parapet above the ground *(o r)* is also twenty-two feet and a half.

a b. *The interior slope of the rampart* has a base *a s* equal to its height *s b*: in this case *a s* and *s b* are each equal to fourteen feet: this slope of 45° is the natural slope at which earth of common tenacity will stand; and it is thus formed, that it may remain stable without support or repair.

b h. *The terre-pleine of the rampart*: it has already been shown that the platforms for guns occupy a length of eighteen feet, and allowing twenty-two feet in their rear for the free passage of the artillery and the defenders; the terre-pleine will then have a width of forty feet.

All terre-pleines have a slight slope or inclination to the rear, to keep them drained from rain water.

k f. *The interior slope of the parapet* has a base *k i* of one fourth of its height *i f*: it is supported by a revêtement of turf or sods (paragraph 76): this steep slope is necessary in order that the guns may be run well out into the embrasures; and also that the musketry on the banquette may lean conveniently against it to fire over the parapet. The total height of the crest of the parapet above the terre-pleine is seven feet and a half or eight feet that the men in its rear may be sufficiently covered and protected by it.

As guns in battery stand at eighteen feet apart, the spaces between their platforms are occupied by banquettes: *the tread or terre-pleine of the banquette (d e)* is raised to within four feet or four feet and a half of the crest of the parapet, that the defenders may fire along its superior slope with ease; it is from four feet and a half to five feet in width, that there may be room upon it for two ranks of men; although more than one is rarely on it at a time: its slope to the rear is made gentle that the defenders may ascend and descend with facility.

f g. The superior slope of the parapet has a base of eighteen feet that it may be shot proof; its slope prolonged (the line of fire of its musketry) should cut the opposite counterscarp; this depression is usually at the rate of two inches per foot: and it is not desirable to give it a greater dip for fear of weakening the crest by too sharp an angle of earth, that could be easily beaten down.

g h t. The exterior slope of the parapet should have a natural slope to prevent its being worn away by the action of weather and time; and, as it is exposed to receive the shot of the assailant's guns, it is well to give it even a greater base than its height. In this fig. the base *z t* cannot be less than eleven feet and a half, where the perpendicular height of the revêtement *(t x)* is thirty feet.

The thickness of the rampart is, from the above,

Interior slope, its base	14 feet
Terre-pleine of the rampart, (including the banquette)	40
Interior slope of the parapet	1½
Superior ditto	18
Exterior ditto	11½
Total	85 feet

Some of these dimensions may in certain cases be reduced or augmented; hence ramparts may be said to average from sixty feet to one hundred feet in thickness.

25. In examining the outline of a fortress, as fig. 1, it is seen that some angles point outwards towards the country, and others inwards towards the place; the former are *salient*, and the latter are *re-entering angles*. An imaginary line that divides an angular work into two parts, bisecting the angle, is called the *capital*.

26. *A bastion* is a work having two faces and two flanks, the angles being all salient (see fig. 1, 20, 14, *r*, *m*, *n*); the angle formed by the meeting of the two faces (14 *r* and *r m*) is *the flanked angle of the bastion:* that formed by the meeting of a face (as *r m*) and a flank (as *m n*) is *the shoulder angle:* and that formed by the flank *m n* and the curtain *n o* is *the curtain angle*.

In standing in a bastion, and looking towards the country, the face and flank on the right hand is called the right face and flank; and on the left hand, the left face and flank.

The mass of rampart and parapet follows the windings of the faces and flanks; leaving, in some cases, an interior space in the centre of the bastion, on the level of the ground; as, for example, in fig. 14, where the half-bastion on the extreme right of the plan is thus drawn: all the space within 5, 5, 5, 5, is on the level of the ground; and at these figures, 5, 5, 5, the rise of the interior slope of the rampart begins; this construction is called a *hollow* or an *empty bastion*. In other cases, as in the centre bastion, fig. 14, the interior space is all filled up to the level of the terre-pleine of the rampart, and the rise of the interior slope begins at 6, 6, 6; this is a *full bastion*.

In fig. 1, bastion 20, 14, *r*, *m*, *n*, the distance (20, *n*) between the inner extremities of the two flanks, is the *gorge* of the work; the prolongations of the adjoining lines (or curtains), *n*, 41 and 20, 41, are the *demi-gorges*. When the demi-gorges and gorge are in the same line, and the former is half of the latter, the work is called a *flat bastion*.

27. The line of rampart that joins the flanks of two bastions together (as *n o*) is the *curtain*.

28. *The ravelin or demi-lune* is a work having two faces, forming a salient angle, placed beyond the main-ditch opposite to the curtain, and separated from the covered-way by a ditch that runs into the main-ditch (as *s*, fig. 1).

29. *Places of arms* are enlargements in the covered-way (see definition 12) at the re-entering and salient angles of the counterscarp; hence the terms *re-entering places of arms* and *salient places of arms:* the latter space is formed simply by rounding the counterscarp, and the former by setting off demi-gorges of twenty-four or thirty yards, and making the faces form angles of 100° with the adjoining branches of the covered-way.

30. *Traverses* are portions of parapet thrown across the covered-way, on the prolongations of the faces of bastions and ravelins, and at the entrance of the re-entering places of arms; passages are cut into the glacis, to enable the defenders to circulate round the traverses.

31. *The tenaille* is a low work in the main-ditch, before the curtain and between the flanks of the half bastions of a front of fortification: it is usually sixteen yards in thickness, and revêted with masonry all round.

32. *A citadel* is a small strong fort, constructed either within the place, or on the most inaccessible part of its general outline; it is intended as a refuge for the garrison, in which to prolong the defence after the place has fallen, or to hold out for the best terms of capitulation. Citadels are generally in positions that command the interior of the place, and are therefore useful in overawing a population that might otherwise strive to shorten the length of a siege, during which the inhabitants are always great sufferers.

33. *A cunette* is a small ditch in the middle of a dry ditch, in order to keep it drained.

34. *A caponniere* is a parapet from seven feet and a half to ten feet in height, having its superior slope terminating in a small glacis; it is placed in a dry ditch, in order to cover the

defenders in passing across the ditch from one work to another, and it has a banquette to furnish a fire of musketry upon the ditch.

35. *A batardeau* is a strong wall of masonry built across a ditch to sustain the pressure of the water when one part is dry and the other wet; to prevent this wall being used as a passage across the ditch, it is built up to an angle at top, and armed with iron spikes: and to render the attempt to cross still more difficult, a tower of masonry is built on it: in the batardeau is a sluice by the opening or closing of which the manœuvres of the water can be regulated.

36. The quantity of earth or soil contained in the mass of the rampart and parapet of a work is called the *remblai*; and the quantity excavated from the ditch the *deblai*: and, in general, the number of cubic yards contained in the remblai has been furnished by the deblai; so as to balance each other.

CHAPTER I.

Necessity for fortifying with the present thick earthen ramparts, parapets, &c.

1. Before the knowledge of gunpowder, which has rendered artillery so tremendous an engine in all kinds of modern warfare, but more especially so in the attack and defence of fortified places, the mode of fortifying was simple, yet particularly calculated for defence against the implements then in use; which, however ingenious and formidable at that time, sink into insignificance, when compared with the irresistible missiles now projected from guns and mortars, by the power generated from the explosion of gunpowder.

2. A thick wall flanked by towers, separated by a ditch from the country, constituted the whole of an ancient fortification:* the towers were within bow-shot of each other, and raised one or two stages above the wall of the enceinte, in order to preserve a command over the latter, should an enemy make himself master of it; as well as to obtain a height sufficient to contend with the great moving towers then used in the attack; these flanking towers were usually separated from the enceinte walls by a cut, having a drawbridge: thus they answered as

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* This rampart wall had, upon its exterior edge, a thin battlemented or loop-holed parapet to serve as a cover for the archers, and to permit them to fire through. And in most cases this parapet was projected like a balcony, having loop-holes in its base, to enable the besieged to see and to defend the base of the rampart wall. This balcony was called Machicoulis, and forms the picturesque projection of old towers as seen at this day.

rallying posts and citadels which required to be attacked, even if the enceinte wall connecting them, was carried; hence the attack was nearly always carried on against a tower in preference to the enceinte wall.

3. To become master of such a place (after having reached the counterscarp or outer edge of the ditch), a portion of the ditch was filled in and a good causeway made across it, to allow of the battering-rams being brought up to beat down the walls; while showers of stones and arrows were kept up from both sides: it would be merely to swell the pages of this work to enter upon the details of attacks and defences conducted according to the science and machinery then known: history furnishes us with numerous and splendid instances of defences. Without going back to the siege of Troy, we find Tyre defended by a manufacturing and trading people, braving the power of Alexander for seven months; the great Camillus triumphed at Vieæ, only after a siege of several years; and Syracuse was sustained for two years, by the genius of Archimedes, against every effort of Marcellus. Besides these and other well-known instances, it is only necessary to peruse history from the earliest periods down to the invention of gunpowder to form long tables of extraordinary sieges, which, when contrasted with the brevity of modern ones, abundantly show how greatly superior the powers of the attack have been rendered by the use of modern artillery.

4. On the introduction of cannon, the shot projected from which can beat down masonry at a distance of many hundred yards, the old high frowning battlemented walls no longer afforded security, as breaches or openings could be made in them without the necessity of bringing the breaching batteries (as with the battering rams, &c.) close up to the wall; and in the attack, the great moving towers and most of the other contrivances were of necessity laid aside, as the shot from the defensive batteries could break them to pieces. A total change, therefore, became necessary in the construction of defensive works and in the mode of conducting the attack, in order to suit the new kind

of artillery and its wonderful agent gunpowder. This agent was discovered about the year 1320, although it was not till 1380 that its power was sufficiently ascertained and regulated to make artillery so formidable as to create a necessity for an entire revolution in the defence and attack of fortified places.

5. In the advance of the mechanical arts, which have of late brought almost to perfection the manipulation of gunpowder, the casting and boring of guns and mortars, the construction of carriages and implements necessary in the transport and use of artillery, the value of this arm has become proportionably greater, and its influence almost paramount in the branch of warfare of which we are now treating.

6. Before entering further into the nature of the works thrown up for defensive and offensive purposes, it will be proper to state here something of the effects of artillery.

In order to obtain advantages from gunpowder, its elastic force is generated and confined in great iron and brass tubes, for the purpose of propelling the balls and shells laid therein. And five hundred years' experience has limited these tubes or *ordnance* to four kinds; viz.—

1. Long guns.
2. Carronades or short guns.
3. Mortars.
4. Howitzers or field mortars.

Long guns and carronades are designated by the weight of the shot that they throw; thus 68, 42, 32, 24, 18, 12, 9, 6, and 3 pounders throw shot of the weight in pounds corresponding to their respective numbers. And the battering guns commonly in use, namely, long 18 and 24 pounders, can destroy masonry defences of every kind at a distance of five or six hundred yards, and are efficient for greatly injuring them even at one thousand yards.

Mortars are for throwing shells, (hollow cast iron globes) nearly filled with powder, which are projected with a high curve, (the mortar being elevated 45°), and fall down nearly vertically upon the object to be struck, being so contrived as to explode at the moment required. Mortars are named from the diameter of their bore in inches, viz.—13, 10, 8, 5½, and 4⅖ inches. Thus these shells may be called small mines, which are projected to be burst at pleasure; carrying destruction with their immense weight and by their fragments, as well as by firing all combustibles within their influence. And the extreme distances to which they can be thrown average (from the least to the greatest mortar) from one thousand to four thousand two hundred yards.

Fire from mortars is called a *vertical fire*, to distinguish it from the more direct fire of large guns, which is called horizontal fire.

Mortars are not mounted on travelling field carriages like guns, but are fixed to solid platforms of wood or iron; hence they are only used, in general, in the defensive works and in the formal operations of a regular siege. Howitzers are mortars mounted on field carriages, and can only project their shells at low angles; they are much used both at sieges and in the field.

7. In the tracing and in the relief of the works of a fortification, ample provision should be made, on the one hand, to ensure the full defensive advantages of these formidable weapons; and on the other, every precaution should be used to guard against their destructive effects from the hands of an assailant.

8. The various ways in which projectiles can be thrown from ordnance may be classed into

1. Direct fire.
2. Oblique fire.
3. Reverse fire.
4. Enfilading or raking fire.
5. Ricochet fire.
6. Vertical fire.

Direct fire is when the battery of guns is drawn up parallel to the line of troops or works to be fired at, so that the shot strike the object perpendicularly to its face. *Oblique fire* is when the shot from the guns strike the object at an angle or obliquely. *Reverse fire* is from a battery in the rear of a line of troops or works, the shot taking it in reverse. *Enfilading fire* is when the battery is ranged at right angles, or nearly so, to a line of troops or works, the shot from the guns raking or sweeping the line in its whole length; when the guns are thus fired with their full charge of powder it is considered to be an *enfilading fire;* but, when fired from the same position, having a slight elevation given to them, and with a diminished charge of powder, it is *ricochet firing:* under such circumstances the shot is deprived of its greatest velocity and describes a curve in its flight, hence it is easy to conceive that on striking the ground it will bound again with shorter hops than if it had a greater velocity. Both shot and shell can thus be made to graze over the crest of a parapet and hop along the work to be enfiladed: although the force will not be so great as with shot fired with the usual charge, it will be sufficiently so to disable guns, carriages, and men, which is all that is required: and shells (from howitzers and long guns) bursting in this manner will have their full effect.

Vertical fire is that already described (paragraph 6) from mortars. In attacking a fortress, the assailant's artillery has two objects to gain, viz. silencing of the defensive batteries and the beating down of the defensive masses and revêtement: to effect the first, he has to establish the enfilading and ricochet batteries just spoken of; and also batteries (both at a distance and on the crest of the glacis) to oppose directly the defender's guns; these are called *counterbatteries:* to beat down the revêtements and make an opening or breach fit to assault, for which purpose batteries are erected on the crest of the glacis called *breaching-batteries.*

Suppose a battery of guns in the attack to be prepared upon the crest of the glacis, to breach the face of a bastion or ravelin opposite to it, and within one hundred feet or one hundred and thirty feet of its revêtement; it is recommended to begin to form the breach by firing so as to cut a horizontal groove with the shot near the bottom of the wall; and at each extremity of it, two perpendicular grooves, so as to detach the quantity of masonry to be brought down from the rest of the wall; salvos are then fired at the detached mass till it is brought down. Therefore, to make an effectual breach either from this short distance or from a greater, it is necessary to see to the bottom of the wall or nearly so; for if the top of the wall be first beaten down, the rubbish will hide the bottom of it from the view of the breaching guns and prevent its being brought down; the slope will then be too steep to be assaulted.

9. These various modes of projecting metallic globes (some solid and some contrived to burst at pleasure) have rendered powerful batteries of artillery capable of sweeping and annihilating all before them; and have reduced the science of fortification nearly to a state of calculation, as to the amount of defence of which any place is capable and the power necessary to reduce it.

10. Some writers have been found to build up their systems on the terrific effects of vertical fire to the prejudice of direct and enfilading fire: and ricochet fire has attained, through the praises of the French writers, a very great reputation; but our practical military philosopher, Col. Sir John Jones, remarks, "That there is no exclusive weapon in the science of attack and defence: it is neither vertical, ricochet, nor direct fire alone, but a judicious combination of the three which will prove irresistible."

11. From these observations, it is seen at once that the old high narrow rampart wall has naturally given place to one of earth of greater breadth and less height; and although it is faced exteriorly with masonry, yet no part of the latter should be seen from the country: for in viewing a well constructed place from without, the masonry ought to be so well covered, that an observer should see nothing but one shot proof sodded

parapet rising over another: hence the assailant is forced to bring his battering guns, by a toilsome and dangerous process, to the counterscarp of the ditch in order to make a breach or opening in the scarp revêtement.

12. The thin parapet of masonry that sufficed formerly to cover the archers and slingers, could be immediately cut through by shot projected by gunpowder; and if it were sufficiently thickened to be shot proof, it is very undesirable to make it so; since the splinters detached from masonry walls by shot striking them, are, at all times, very dangerous, and do much execution amongst those who are near them. A parapet of earth has therefore superseded that of masonry; and as the shot from heavy guns can penetrate from twelve feet to fifteen feet into a bank of earth, the thinnest part of the parapet at top is made eighteen feet, and its base occupies from twenty-five to thirty feet.

13. Definitions 11, 22, 23, and 24, detail most fully the names and general dimensions of the ramparts, parapets, and banquettes, which have come into use with the ordnance just described, and with which the learner must be familiar ere he can attempt to pursue with advantage the following statements.

14. By being placed behind a massive earthen parapet, the defenders are so far removed from the ditch before them, that it is impossible for them to see or to defend it; as in fig. 13, the superior slope of the parapet *f g* prolonged (the line of their fire) only cuts the top of the opposite counterscarp: such a defect as an undefended ditch, or piece of *dead ground*, must not, if possible, be permitted to exist within range of the defensive weapons, even outside of the place, but assuredly not in the ditches; in which an enemy may either collect in force, or employ his miners to penetrate the rampart and blow it up; it therefore becomes necessary to trace the works so as to obviate this defect.

15. By referring to fig. 2, which represents the tracing of a part of a square redoubt, it is plain that the defenders placed

behind the parapets *n o*, *m p* cannot see any part of the ditches, which are consequently altogether undefended; if, to remedy this, the face *m n* be broken, so that the parapet be made to follow the triangular tracing, *a*, *b*, *c*, then the musketry on the banquette, from *a* to *e*, will be enabled to defend about as much of the ditch as is seen from *h* to *b*; those from *c* to *g* can defend a portion of the ditch *i b*; the fire over the superior slope of the parapet from *a* to *d* will reach and defend the bottom of the ditch at *k*; and that from *c f* can defend *l*; thus a considerable portion of the ditch, at the angles *a* and *c*, remains undefended; consequently this tracing (which is called the *redan* tracing) does not entirely rectify the evil of dead ground in the ditches; and if any other mode of laying out the works be tried, it will be found that none will completely succeed in doing away with unflanked ditches but *the bastion system*, a tracing so called from the name of the great works (bastions) at the angles of the polygon: fig. 1 represents this tracing. Here the defenders placed on the banquette, on the line *p o*, see the bottom of the ditch *z*, on the line *s t*; consequently they can defend it up to the revêtement wall *m n*, and also along its length *m r*, as indicated by the lines of fire: in like manner the defenders on the banquette behind the line *m n* begin to see the bottom of the ditch *z* on the line *s t*, defend it up to the wall *p o*, and along its length *p q*; thus, the whole of the ditch *z* is fully and efficiently flanked.

16. This bastion tracing having been evidently contrived to defend ditches from behind thick parapets, there will be no necessity to enter here upon what is sometimes called the history of the bastion system, which some engineers date as far back as the beginning of the fifteenth century: because thick ramparts and parapets must have followed immediately on the increased power arising from gunpowder artillery.

17. Although their present form can be dated from the beginning of the fifteenth century, yet the ancient towers at the angles of the long walls or curtains were a species of bastion, being in some measure intended for the same purpose; namely,

looking into and defending the ditch: consequently, bastions may be considered as having had their existence in the earliest ages; and hence any attempt to trace their origin would not only be fruitless but uprofitable.

18. Definition 26 details the shape, and gives the names of the various parts of a bastion, and of the enceinte; to which the student is referred.

19. The mass of rampart and parapet, and also the main-ditch, follow the windings of the lines called bastions and curtains; and this first enclosure is the body of the place: on it, the heaviest ordnance is mounted for the defence; but, by examining the nature of the defence produced by such a simple enceinte, with a covered way before it, (as in fig. 1, fronts *q b*, *b* 4), it will be seen that something more than this first line of works is necessary: for suppose, in this figure, that the defenders on the faces of the bastions (*b* 22, *b* 23) fired straight before them or nearly perpendicularly to these lines,* then would there be a sectoral space (24) before the flanked angle of the bastion, undefended by a direct fire; and although the fire of the flanks (26, 27 and 21, 25) fully defend the ditches that they look into, they could but feebly sweep the dead ground spoken of, because the crest of the salient places of arms of the covered-way (28) would greatly obscure the view of the country from the guns in battery on the flanks (26, 27 and 21, 25); and the musketry fire from these flanks is too distant to reach the ground (24) before the flanked angle of the bastion: it is true that a musketry fire can be obtained from the faces of the re-entering places of arms (2, 31), which would flank the undefended ground (24) before the bastion, but this is not sufficiently powerful to constitute a sufficient defence: besides which, once in the covered-

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* Although artillery is always pointed as far as the opening of the embrasure permits; and although musketry is likewise directed towards the object required, yet as a fire has sometimes to be kept up, either in the obscurity of darkness, fog, or smoke, it is usual to calculate upon a fire being delivered perpendicularly to the face of a work or a line of troops.

way and its re-entering place of arms (31), the enemy arrives at the bridge or passage leading through the enceinte into the place.

20. In order to rectify these defects, a work has been constructed immediately beyond the main-ditch at the re-entering angle of its counterscarp, which, from its original semicircular shape, was termed the demi-lune or half-moon; but which has been long since altered to the angular shape shown in fig. 1, *s*, and is indifferently termed the demi-lune or ravelin (definition 28). Its ditch, which separates it from the covered-way, runs into the main-ditch; and from the ramparts of its two long faces, a strong and close fire of artillery and musketry is obtained, to flank effectually the approaches to the flanked angles of the adjoining bastions right and left; the faces of which bastions *r m* and *p q* fully bear by their fire upon the approaches to the flanked angle of the ravelin.

21. Before proceeding further to illustrate the principles upon which the various works are arranged, it may be well to state, that the present system which has obtained a preference in Europe, was perfected by *le Maréchal de Vauban*, of the French army, who served during part of the reigns of Louis XIII. and Louis XIV.; and whose profound knowledge of mathematical science, joined to his unprecedented experience as a military engineer, have rendered his works the standard, to which both the theory and practice of most modern officers, of all armies, have greatly conformed.*

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* Various changes and improvements have taken place in the bastion system; but most of those of an early date were encumbered with systematic suppositions, which rested either upon long established prejudices or adherence to mathematical reasonings, in preference to the results of practice. *Henry IV. of France* appointed his prime minister, the great *Sully*, to be superintendent of fortifications; the latter confided the conduct of his works to a corps of engineers: *Errard de bar-le-duc*, one of the principal officers of this regiment, was charged to write a treatise on the art of fortification, in order to spread the knowledge of it in his own corps, which he did in the year 1594. In 1629 *Le Comte de*

CHAPTER II.

On the principles of the tracing of Vauban's first system; with remarks.

22. When the situations are considered and examined, in which fortresses are generally constructed, it will be found that the works usually rest upon irregular and unequal ground; or on

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Pagan produced a work which disengaged the art from much of its rubbish: having attained, through a brilliant military career, the high rank of Maréchal de Camp; he became blind at thirty-eight years of age, and therefore no longer capable of fulfilling the active duties of his profession. *Vauban* was born in 1633, and in 1665 (the date of Pagan's death) he had already acquired reputation at the siege of *Sainte Menéhould*, of *Stenay*, and of *Landrecie*. Vauban followed up the principles founded by Pagan, and applied them with great skill in a most extensive practice, for he built thirty-three new fortresses, and repaired or improved one hundred: his executed works, and a few memoirs, remain for the admiration and instruction of those who have followed him in this department of military science. From these it has been customary, in schools of instruction, to form three systems, which have acquired the names of *Vauban's first, second, and third methods of fortification*. The exercise of his talent was not confined to defensive works, and to all the intricate detail of the construction of fortresses; but serving an ambitious monarch, for whom he conducted fifty sieges, he perfected a powerful and resistless system of attack, which has ever since been successfully followed; and thus he afterwards neutralized that superiority to which he had attained in the construction of his defensive works.

Cormontaigne entered the corps of French engineers in 1716, (nine years after Vauban's death) and died as a *Maréchal de Camp* in 1750; following the principles of Vauban, he improved the detail of his systems, and the most approved method is Cormontaigne's with some slight changes.

By referring to a work published in 1801 by Mons. Mandar, entitled "De l'Architecture des Fortresses," no less than one hundred and twenty different methods will be found, which have been proposed from time to time, (as well as others not named therein); many of them deserving great consideration, and manifesting much military genius: but it is a truth confessed by all engineers, that a thorough knowledge of ground presenting natural obstacles on some sides, and facilities on others, for the approach of an enemy. Fortresses usually cover commercial marts, dock yards, harbours, &c. and their defensive properties may be, and generally are, increased from the navigable rivers, islands, marshes, or commanding positions, that are to be met with in such cases. When some sides of a place are inaccessible or very difficult of access, from these or from other causes, it would be quite needless to present there a succession of fronts of bastions, ravelins, and covered-way; such sides require only to be enclosed by a simple rampart with artillery in barbette or embrasure, to command the obstacle or the ground beyond it; while fronts liable to be attacked are protected by an accumulation of works and artificial difficulties; and for these reasons almost every existing fortress is irregular (definition 8).

23. In examining the works of Vauban, it is found that, in the general outline, he used various lengths for the sides of his polygons of fortification, which have been accordingly classed into *great, mean, and small fortification:* and as some general principles are to be traced through the whole of his works, it will serve to illustrate the subject, if the investigation of his first method* be arranged under the following heads.

1. The general outline, and form of the works.
2. The lengths of the various lines and works.
3. The openings of the different angles of the works.

Vauban's principles of defence and attack, and of the advantages and defects of his constructions, will enable a right judgment to be made of every other method; and, accordingly, in this treatise, his principles are closely followed and illustrated.

* It is necessary for pupils to remark, that in this investigation the works are supposed to be constructed on a horizontal plain; inequalities of ground, either on the site of a fortress or in the neighbourhood, form a separate and difficult subject, treated of in Chap. xii. It is also to be noticed, that although the principles of Vauban's first system are explained, they are also discussed, and the opinions of approved modern engineers of experience, on their properties, are given.

24. First. *On the general outline.* From thé remarks in paragraph 22, it follows that the assailable fronts of a fortress should be carefully and perfectly constructed, and that those covered by natural obstacles will suffice if barely enclosed by a single line of works: accordingly, in examining most existing places, this is found to be the case; the general outline presenting some long simple fronts, either crowning inaccessible heights, or covered by rivers, marshes, &c.; the fronts liable to attack are of a medium length, carefully traced and relieved, with a regular system of outworks; and where advanced or detached works (definitions 14 and 15) are thrown out, they are generally found constructed on short or contracted fronts: this has given rise to the classing of the fronts into *great*, *mean*, and *small:* the great fronts average from one hundred and eighty-five to two hundred and fifty toises: the mean from one hundred and seventy to one hundred and eighty-five toises: and the small from one hundred to one hundred and seventy toises. Their application is illustrated in fig. 29, (which is an outline of the fortress of Badajoz* in Spain, as defended by the French, and besieged by the allied army under the Duke of Wellington, in 1812): the three long or great fronts *ki*, *ih*, *hg*, are covered by the river Guadiana, its tributary stream Rivillas, and the scarped rocky ground on both sides of the castle *h;* for these a simple rampart mounting artillery, to command the ground beyond the obstacles, is sufficient; these sides are about three hundred toises each: indeed, from *h* to *k* may be considered as one long front broken into flanks and towers, following the shape of the ground. The other fronts that are exposed to attack, viz. *ha*, *ab*, *bc*, *cd*, *de*, *ef*, *fg*, are of the mean length of about

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* The plan of Badajoz has not been selected as a specimen of a well fortified place, for its defects are many; but it is taken simply to show the application of the great, mean, and small fronts, as well as some other principles that its works and localities serve to illustrate; besides which, the details of its sieges are still fresh in the memories of the veterans of the service; and the exploits at these sieges enter into the records of no less than nineteen regiments which were employed in its arduous attacks.

one hundred and eighty toises; and the advanced work *L*, as well as the detached works *P*, *T*, *S*, are constructed on small fronts of from fifty to one hundred toises in length: the enclosure that crowns the summit of the height *h* is the castle of Badajoz, and serves as a citadel; were a regular work erected on it, suited to the objects of a citadel, (definition 32), the fronts would, from the nature of the ground, be small: it is, therefore, usual to state that small fronts are applied to great outworks, advanced works, and citadels: how far it is judicious to construct a regular front on a less side than one hundred and eighty toises, will be seen as the pupil advances; unless it be on restricted ground, such as in the case of the detached work *S*, fig. 29. It becomes necessary however to explain the reasons for fixing the lengths of mean fronts at about one hundred and eighty toises: for which purpose, refer to fig. 14; where all parts of the enceinte are within mutual range of musketry; now, the longest range is the line of defence, that is, the line *o* 8; for the defenders upon the flank *c o* have to defend all the ditch before the face of the next bastion *h* up to 8, and even to *a b*; therefore this length *o b* ought not to exceed the effective range of the muskets used upon the flank. It will soon be seen, as the pupil proceeds, that the lengths of the faces and flanks of the bastions, as well as of the curtains, are not arbitrary, but become so dependent upon fixed principles as to force the tracing to be what it is in fig. 14; which brings the line of defence within the range of musketry; and the desired advantage of all parts of the enceinte within mutual musketry range. But if the exterior side 8, 9 were more than one hundred and eighty-five toises, the length of the line of defence would exceed the effective range of musketry, and the consequence would be, that the portion of the main-ditch about the flanked angle of the bastion would labour under the disadvantage of being undefended by a musketry fire: it appears, therefore, that the exterior side of the polygon of the mean class is made as long as it can be without sacrificing a mutual defence throughout the enceinte.

If it be asked whether the exterior sides of the mean class might not be made less than one hundred and seventy toises, the answer is, that they cannot be without detriment to the defensive properties of the works; for in proportion to the front being lessened, the boldness of the relief diminishes; besides which, no object can be gained by surrounding a place with a polygon of twenty sides, when one of fifteen would produce a better defence; to multiply the fronts is to multiply the bastions, to abridge their power by contracting their faces, flanks, and interior space, and to render the fronts altogether more feeble.

Viewing a fortified place as enclosed by great, mean, or small fronts, according to circumstances, the general outline of the works consists of a succession of salient and re-entering angles affording each other a mutual defence.

25. With respect to the 2d head mentioned at the end of paragraph 22; namely, *the lengths of the various lines of works* of the first system of Vauban, (as seen in the mean fronts *a r*, *r q*, *q b*, of fig. 1), let the enceinte be first considered; and here, as the length of the faces of the bastion depends greatly on that of the flank and curtain, it is necessary to show on what principles the lengths of the latter works are determined: the flank *m n* being armed with musketry and artillery, requires to be long enough to defend the main-ditch by its fire; and as it has also to contend with the enemy's counterbattery (paragraph 8) established on the crest of the glacis opposite to it, at *c*, where the assailant has a space equal to the width of the main-ditch at the salient angle, (in the case of a dry ditch, it is fifteen toises, added to that of the covered-way, five toises, in all twenty toises), the flank *m n* should not be less than twenty toises long; but to give it a preponderance it has a length of twenty-seven toises, which enables the defenders to place more guns upon it than the enemy can in the only space, *c*, from which he can directly counterbatter them.

26. In the front *r q*, fig. 1, the musketry defenders on the flanks *m n* and *p o* have to defend the main-ditch, so that the

fire from their muskets, depressed over the superior slope of their respective parapets, must meet at the bottom of the main-ditch, upon the perpendicular, (paragraph 15). Now supposing the superior slope of these parapets to have the usual depression, (definition 24) their prolongations should meet at the bottom of the ditch on the line *z*: a slight consideration will show that the distance to which these flanks must be removed from each other (and this distance is the length of the curtain) must depend upon their relief, (definition 20). In the system now under discussion, when the relief of the enceinte is forty-four feet, the length of the curtain is about seventy-three toises.

27. The lengths of the flank and curtain being regulated in the manner just described, the remaining part of the lines of defence *m r* and *p q* form the faces of bastion; and as these faces carry the most powerful batteries, it is desirable to have them as long as possible, consistent with a proper length of flank and curtain: here (fig. 1) it is about fifty-one toises.

28. Again, it is necessary that the line of defence *r o* should not exceed in length the range of the destructive fire of musketry, that the defenders upon the flank *p o* may be enabled to sweep all the main-ditch *z z* up to the rounding of its counterscarp, and also the salient place of arms before it:* now this is effected by the tracing just named, when the exterior side of the polygon is about one hundred and eighty toises; were it more or less, the consequences already named (paragraph 24) would ensue; besides which, when the enceinte has its usual relief, (namely, about forty-four feet) giving a curtain of seventy-three toises in

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* If this line from *o* (the curtain angle) to *d* (the salient place of arms) be measured, it will be found to be about one hundred and fifty-five toises or three hundred and ten yards: formerly *rampart muskets*, of a large calibre, were used for arming the flanks to command this long range; but the strength of gunpowder has been so much increased since Vauban's time, that common muskets will now suffice, although this is a very long range for them; in the modern system this range is shortened to two hundred and ninety yards, which is better.

length; and that the flanks and faces of the bastions have also the respective dimensions just named, then nothing less than a mean exterior side will admit of these arrangements. If the exterior side of the polygon belongs to the small class of about one hundred and twenty toises, it would be impossible to give the enceinte a relief of forty-four feet, providing for it, at the same time, all the flanking and defensive properties hitherto considered; therefore in proportion as the side of the exterior polygon becomes short, a bold relief must yield to one of less height, which of course gives shallower ditches, lower revêtements, and less formidable works.

29. As nothing less than one hundred and eighty toises, exterior side, will admit of the construction of a front possessing the best defensive properties, it is questionable how far the third or small class of fortification should be admitted in practice, unless it be in cases where the ground on which the works are constructed is so restricted that a full and efficient front of one hundred and eighty toises cannot be obtained; or where, as in field fortification, works of a slighter character will suffice.

30. In the construction of Vauban's first system, (app. No. 3) it is stated that the perpendicular is made one-eighth of the exterior side in a square; one-seventh in a pentagon; and one-sixth in a hexagon and in all superior polygons: the length of the perpendicular depends on the length that is proper to give to the flanks of the bastion; for instance, in fig. 5, fronts *b c* and *c d*, the perpendicular *e f* is short; and in the adjoining fronts *a b* and *a d*, it is longer, which (under every other similar circumstance) gives short flanks in the former, and long flanks in the latter, fronts. What the proper length of flank should be has been already stated (paragraph 25); the conclusion is that the perpendicular should be long enough to give this required length of flank; and one-sixth of the exterior side suffices to do so; therefore in no case is it ever made more. It remains, however, to explain why it is made less in the cases of a construction on a square or a pentagon; now let the effect of

a long perpendicular be considered (in fig. 5) as it affects the flanked angle of the bastion, and it is readily seen that, in proportion as the perpendicular lengthens, the flanked angle of the bastion becomes more acute: the angle of a square (fig. 5) is only 90°, and that of a pentagon 108°; then if, to the fronts on these low polygons, the full perpendicular of one-sixth of the exterior side were given, as in fronts *a b* and *a d*, the interior of the bastions would become so contracted, from the acuteness of the flanked angle, that their efficiency would be greatly diminished, and the gorges nearly closed up (as *n a o k*, fig. 5): to prevent these evils, and to keep the bastions as large as the acuteness of angles of the polygon will permit, the perpendicular is shortened to one-seventh of the exterior side in a pentagon, and to one-eighth in a square, which in the latter case reduces the flanks to twenty toises in length; but as the angle of the pentagon opens 18° more than that of the square, the perpendicular may be increased from one-eighth to one-seventh of the exterior side, in order to obtain as long a flank as possible, without rendering the flanked angle too acute; and in the hexagon, as the angle is 120°, the perpendicular can be made one-sixth or its full dimension, which never varies in higher polygons, as it gives the necessary length of flank, in all ordinary cases.

31. In the low polygons of a square and pentagon, as the flanks are thus shortened, their capability to defend the main-ditch is also lessened; consequently, it has been customary to reduce the breadth of the latter to fourteen and thirteen toises at the flanked angle.

32. Thus the width of the ditch and the length of the flank that defends it, operate mutually on each other; and when, from the above or any other cause, it becomes necessary to shorten the flank that has to defend a ditch, the latter should be narrowed also; and the converse of this should likewise be kept in view, namely, that when it is necessary to widen a ditch, it should have a flank capable of defending it efficiently.

Although the foregoing paragraphs have been requisite to explain the mode of regulating the perpendicular and flanks in low polygons, yet it may be well to remark that works of a permanent character are rarely or ever constructed on a square or pentagon, except in the cases of citadels (definition 32): the angles of the polygons of fortresses of a respectable size being usually 130° or 150°, which is an opening sufficient to admit of large spreading powerful bastions.

33. In the tracing of the first system of Vauban, the counterscarp of the main-ditch (*p d*, fig. 1) is drawn from the shoulder angle of the bastion *p*, to be a tangent to the arc *d;* by this, the whole flank *p o* can deliver its fire along the ditch to be defended; whereas, if the counterscarp were drawn parallel to the face of the bastion, as is the case in fig. 5, front *a b*, where *h i* is parallel to *h b*, then the ditch would be directly defended by only that portion of the flank *h k* that can look along its whole length, and it would be deprived in a great measure of the benefit of the remaining part (*k o*) that could only see it partially.

Thus have the leading features of the tracing of the enceinte of the first system been explained; and it now remains to show the principles upon which the outworks, covered-way, and glacis have been traced, as far as their outline and length of line is concerned.

34. The ravelin or demi-lune (definition 28) has a capital *e f*, fig. 1, front *r q*, of fifty toises; and its faces *f g* and *f h* are directed to points at five toises from the shoulder angles (*m* and *p*) of the bastions in its rear: this makes the faces of the ravelin about equal to those of the bastion; and considering that these lines have to defend and flank the ground before each other respectively by a cross fire, and that this mutual support is of equal importance to each, they have accordingly about an equal length of rampart in their faces: the ditch of the ravelin has its counterscarp parallel to its escarp, and receives a full flanking defence from those portions of the faces of the bastions that look into it.

35. The covered-way (definition 12) is formed by the crest of the glacis passing around in a succession of salient and re-entering angles, all within easy musket shot of each other; it is traced at five toises parallel to the counterscarp of the ditches, that the defenders may have room enough for all necessary movements within the glacis; and the places of arms (definition 29) give space for the assembling of considerable bodies of troops when required.

36. By reference to paragraph 23, the 3d head there mentioned still remains to be explained; viz. *the opening of the different angles of the works.* In fig. 5, the defenders on the faces of the bastion *n*, *a*, *o*, being supposed to fire perpendicularly to the parapets behind which they are placed, there will be a great sectoral space *s* before the salient angle, undefended by a direct fire; hence the capital prolonged which leads to this angle is the least defended line: and the most proper for an assailant to select on which to approach the work from the country: now this sectoral space, undefended by a direct fire, becomes less and less in proportion as the salient angle of the work opens, and greater as it becomes more acute; in this respect, therefore, obtuse are preferable to acute angled works: besides which, there may be said to be two more reasons for the superiority of obtuse angled works: 1st, they give greater interior space, and thereby admit of larger bodies of troops and of more artillery being used in them; which, of course, increases their importance and power: the artillery too can be worked freely close up to an obtuse angle; whereas the gun carriages on opposite faces near an acute angle will interfere with each other. 2d, an acute angle having less solidity than an obtuse one is sooner injured by the action of time and the weather; as well as more readily beaten down by artillery

37. The influence that the perpendicular exerts on the flanked angle of the bastion has been already noticed in the latter part of paragraph 30; and it will now be more clearly seen, by the above explanation, that the perpendicular must never be made so long as to choke up the valuable interior space of the

bastion; but that while the proper length of flank is attended to, the opening of the angle of the bastion should be as great as circumstances will permit.

38. It has been considered as a principle that the salient angle of a work is never to be less than 60°; thus for example, in the construction of an advanced lunette *D*, fig. 30, the flanked angle is thrown as much in advance as this general rule will permit, that is, the triangle *g o g* is equilateral, which of course gives the least angle or 60°; while the sides of the triangle *g o*, *o g* are each equal in length to the range of musketry.

39. Re-entering angles being, in most cases, angles of defence, their opening should be regulated with reference to the best situation in which artillery and musketry can be placed for the use of these weapons. For example, take the flank *p o*, fig. 1, front *rq*, in the parapet of which embrasures are opened to permit the guns to defend the ditch; if the angle of defence *r o p* be a right one, the embrasures are then cut perpendicularly through the parapet, which would not be the case if the flank stood either at a greater or a less angle than 90° to the line to be defended; but the embrasures would have to be oblique to the parapet, which should be avoided if possible: for in fig. 6 the gun on its carriage behind the embrasure *a* that is perpendicular to the parapet, can be run up so that both wheels are checked by the hurter, and the piece itself is run clearly into the embrasure; whereas, in the oblique embrasure *b*, the off wheel alone is checked by the hurter, the near wheel being at some distance from it, which prevents the gun being run out clearly into the embrasure. This is injurious to the stability of the embrasure, for the flash and concussion from the discharge of the piece generally injure and shake the cheeks; and, therefore, the farther the gun can be run out into a wider opening, the less will the discharge injure the embrasure;* this can be, and is, generally obviated

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* Hence long guns are preferable, in earthen embrasures, to carronades, howitzers, or short guns; the flash from the latter taking place,

by the construction seen in embrasure *c*, where the crest of the parapet is made perpendicular to the line of fire *de*, so that the gun can be run out as clearly as in embrasure *a*; but this obliquity of embrasure, besides having this troublesome construction, cuts up the merlons more than do perpendicular embrasures; and for these two reasons the latter are preferable, except in cases where a flanking work cannot be made perpendicular to the work flanked: the general principle then, is, that angles of defence for cannon should be right angles.

40. In Vauban's first system, the angle of defence is 82°, which is sufficiently near a right angle to obtain all the advantages required by perpendicular embrasures; although in the modern system it is made exactly a right angle.

41. In some old fortresses and constructions, the flank of the bastion is seen to stand at an acute with the line of defence, (as in fig. 1, front *q b*, flanks 22, 32) having a space 32, 33 betweeen it and the line of defence, called *the second flank or flank of the curtain*, intended to carry artillery in oblique embrasures to aid in flanking the main-ditch and contending with the opposite counterbattery. When the line of defence thus falls upon the curtain, it is called *a line of defence fichante;* but when drawn as usual to the curtain angle, it is *a line of defence rasante:* the former is evidently a defective construction, as it interferes with all the principles already laid down; viz. it increases the length of the line of defence, which is already almost too long; it contracts the interior space of the bastion; it obliges the embrasures to be made very obliquely, &c. without giving any compensating advantages from a weak and ill directed additional flanking defence.

42. Those portions of the faces of the bastions that look upon and defend the ditches of the ravelins are seldom or ever

almost within the narrow neck, soon renders the embrasure a shapeless opening; and when the cheeks are lined with fascines, or long faggots of brushwood, &c., they are liable to be fired and destroyed by the flash from short guns.

at right angles to the parts defended; the embrasures are consequently oblique to their parapets, and this construction must be adopted unhesitatingly, whenever it becomes necessary.

43. In examining the tracing of the covered-way, which is laid out to suit a musketry fire, the faces of the re-entering places of arms stand at an angle of 100° with the adjoining branches of the covered-way; and the reason why angles of defence for musketry are 10° more than those for cannon is that the latter are always regularly laid and pointed; whereas a man with a musket firing over a parapet, in cases of darkness, fog, smoke, or confusion, is very likely to vary the inclination of his musket to the right or left, out of a line perpendicular to the parapet, which deviation may carry the fire upon his comrades in the work flanked: to prevent accidents of this kind, angles of defence for musketry are usually made with an opening of 100°.

44. In considering the general outline of the defensive masses (as in fig. 1), and in supposing that an enemy in a steady regular siege approaches in an equal manner with his trenches over the ground which he occupies, he will first arrive at the most projecting points of the covered-way: now in fig. 1, where the salient places of arms are all nearly in the same circumference of a circle, as c, 34, 35, and 36, he can establish his batteries for counterbattering and breaching (paragraph 8) the body of the place and the ravelins at the same time; but in fig. 25, the salient places of arms before the ravelins project so much beyond those of the bastions, that the assailant would be taken in flank and in reverse, did he attempt to lodge himself at *i* before the bastion, by the faces of the adjoining ravelins that completely command the space *i*; the ravelins must therefore be first taken, or their defences entirely silenced, before the bastions can be regularly attacked, a delay highly favourable to the defence; hence great salient and deep re-entering angles tend in general to increase the defensive properties of works.

CHAPTER III.

On the uses of the works.

45. It is now time to consider the uses of the various works of a regular front according to Vauban's first system, the way in which they mutually flank and aid each other, and their respective properties: and, in examining each work, two things must be kept in view; the first is its intrinsic value; and the second is its relative value: the former includes the extent and power of fire that the work can bring upon the surrounding country, what obstacle it offers in itself to an enemy as to its inaccessibility of situation, its ditch, height of revêtement, and its resources to prolong its defence to the utmost: the latter refers to the extent of influence that a work exerts upon the neighbouring ones, or they upon it, by its capability of giving or receiving assistance.

46. Before entering upon these details, it may be well to remark that the two weapons to be brought into full operation upon all the ground over which an enemy must advance, are musketry and artillery: for the first, (whose range is the shortest), there is provided a sheltered advanced position outside of the ditches (the covered-way) from which a fire can be kept up all round the fortress: this formidable line of musketry is supported by (the faces of the bastions and ravelins or) strong batteries of artillery whose fires cross in every direction: so that every advantage to be derived from the defensive weapons is secured in the best manner by the positions of the works: and viewing the field to be defended in this light, the most convenient mode of entering upon the merits of the works will be to begin with the covered-way or musketry position, and then pass on to the outworks and the body of the place.

47. The covered-way being thirty feet broad, and having a parapet or glacis on its exterior, the crest of which is from seven feet and a half to nine feet in height; it affords in the first place, a secure road of communication all round the fortress, outside of the ditches: here guards and sentinels are placed, which prevent all access to the counterscarp of the ditch, to reconnoitre its state or dimensions; an evil against which it is difficult to find a remedy in fortresses unprovided with a covered-way, during dark and tempestuous nights: and as the banquette is but four feet and a half lower than the crest of glacis, a strong palisading* is placed at the foot of the interior slope of the glacis, to prevent any attempt at forcing a passage into the covered-way. Secondly, from the covered-way, a close grazing fire of musketry is obtained upon the glacis and the surface of all the ground without. Thirdly, bodies of troops can be formed in the covered-way and its places of arms, to act defensively or offensively by sorties;† although there is room in the covered-way for its defenders and all their operations, there would not be convenient space for the assembling of such bodies of men as are required for sorties, were it not for the places of arms (definition 29). The re-entering place of arms also affords by its position a

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* The wooden palisades used in fortresses are, in general, very massive, being wedge shaped, the flat side inwards and about nine inches broad; they are sunk two or three feet into the earth, where they are attached to a heavy beam, as well as bound at top by a ribbon: they stand at nine inches asunder, so that the defenders on the banquette fire between them; they are pointed at top, and are no higher than the crest of the glacis, that they may not be seen from the country.

† A sortie is an attack made by a body of troops that issue from the place, upon some of the works or parties of the assailant: well managed sorties are of much importance in prolonging the defence, either by destroying some of the enemy's works, or obliging him to proceed with great caution, and thereby gaining *time*, which is of the utmost importance to both parties; a gain to the besieged, and a loss to the besiegers. Passages are prepared in various parts of the glacis to facilitate the egress and ingress of sorties.

flanking fire upon the ground before the adjoining branches of the covered-way. In a fortress without a covered-way, troops for sorties or offensive purposes must be formed either within the main works when the ditch is wet, or in the ditches when they are dry; in the former case the defenders are seen by the assailant's batteries the moment they begin to defile across the bridges: or in the latter, as they appear by successive files on the top of the counterscarp; consequently their regular formation is broken from the first, and the power of their attack thereby greatly diminished: and as sorties issue for a specific purpose, such as to overthrow some of the enemy's works, to burn or destroy a part of their siege materials, to spike their guns, &c., the assailant has generally time to collect a force sufficient to oblige the sortie to retreat in haste; regularity cannot then be always preserved in a way that is necessary to check an overpowering assailant pressing on a party that have merely narrow passages, (as staircases down the counterscarp in dry ditches, or bridges in wet ditches), by which to retire; confusion and loss are then most likely to ensue; not to speak of the possibility of a bold rush being made to follow the sortie into the place.

Whereas, in a fortress provided with a covered-way, the sorties form in the various places of arms, on the fronts required; the cavalry ready to mount, the light artillery horsed, the columns of infantry regularly formed, and the working parties paraded with their entrenching tools, &c., to demolish the enemy's breast-works or parapets: while the crest of the glacis is lined in every direction with light artillery and musketry: the sortie issues by many passages cut through the glacis, (either so obliquely or curved that the enemy cannot enfilade them), and immediately proceed to the attack: the work being accomplished, the party retires in like manner, protected by the near fire of their comrades within the glacis, where a secure position is at once afforded them to face about and repel all further attempts.

48. It may be said that sorties are usually made at night and that the advantages of the covered-way are too much mag-

nified in this respect, in the foregoing paragraph: in answer to which it must be remembered that military leaders do not in general approve of night attacks, except in peculiar cases; and that the proper hours for making sorties must depend on circumstances: but if made a little before daylight, as is often recommended, still the covered-way will offer all the advantages already named to the retiring sortie after their duty has been executed, and the day has broken.

49. Fourthly, the crest of the glacis being on an average about eight feet above the level of the ground, the scarp revêtements of the main works in its rear, can thus be made eight feet higher than would be possible if there were no glacis; for it has been already shown how necessary it is to hide all the revêtements from the fire of distant batteries: thus a most important result is obtained by the covered-way and glacis, in the increased height of the scarp revêtement.

50. Fifthly, the exterior part of the fortification, namely the glacis, presents to an enemy an indestructible bank, (for the slope is scarcely two inches to a yard in length) exposing its whole surface and all beyond it to the fire of works in the rear: up this glacis the assailant must work, and must reach its crest ere he can see the revêtements of the place: here he is in a position exposed to the fire of all the remaining defences; and by its elevation, greatly interfering with, and masking the effects of, his own batteries in the rear. And sixthly, he cannot descend to establish his batteries in the covered-way, for it is only thirty feet broad; which, although quite wide enough for all the necessary movements of the defenders, is too narrow for the assailant to construct a parapet next to the counterscarp and to work his guns behind it; for this would require a space of at least forty-four feet, and as the crest of the glacis is but thirty feet from the counterscarp, there would remain fourteen feet of glacis to cut away from the crest; a proceeding too long and too laborious to be contemplated in common cases.

51. The covered-way being a low-work, it is subject to the disadvantage of being easily enfiladed and ricocheted by the enemy's batteries (see paragraph 8); and to lessen the effects of this destructive fire as much as possible, traverses (definition 30) are thrown across its breadth at intervals of about twenty toises; the traverses have their crests as high as the glacis, and are generally perpendicular to the covered-way; these masses of earth stop the shot projected from the enfilading batteries of attack; and to do so effectually, they should never be more than twenty toises apart, that if a shot ricochets over one traverse, it may be stopped by the next. Traverses are made on the prolongations of the parapets of the faces of the bastions and ravelins, since there is no direct fire on these spots from the parapets themselves: they are also always made at the entrance of the re-entering places of arms, in order to close in these important rallying posts to the covered-way. Traverses are made to face towards the salient places of arms, as they are intended to assist in disputing the possession of the covered-way with the assailant, who, in the general progress of the attack, enters the salient places of arms first, where a fire is brought upon him from the two traverses, right and left; and should the defenders be driven from them, they retire behind the next traverses, and continue to dispute the covered-way till they reach the re-entering places of arms.* Traverses in the covered-way are palisaded to hinder an enemy forcing himself over them; and a barrier gate connects the palisades of each traverse to those of the glacis.

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* As all the faces of the works (whose prolongations fall upon ground without, upon which an enemy can establish himself) are subject to be enfiladed; traverses are usually constructed on them between every two guns, to neutralize the effect of this otherwise destructive fire: these, however, are not made till the siege begins, and are merely passive mounds of earth, and not intended for defensive purposes, as in the covered-way.

52. In order to permit the defenders to circulate with ease around the covered-way, the crest of the glacis is formed as seen in fig. 7, *a b*, *c d*, which is called the double crotchet; or as *e f*, the single crotchet passage: the former is Vauban's construction; and the latter was introduced as an improvement by Cormontainge, and has been continued in the modern system: the cause of this change from the double to the single crotchet passage is that the defenders behind the traverse *g* cannot see into the whole of the next crotchet *b a*, and that a few men of an attacking party might find shelter from the fire of the traverse *g* in the nook *b*; this is remedied in the single crotchet *e f*, where the fire from the traverse *h* can defend the whole space *e i*.

53. Notwithstanding this alleged improvement, it is yet a question which construction is best; for in fig. 7, let it be remembered that the crest of the traverse *l* is four feet and a half higher than the banquette *k* of the glacis in its rear; therefore, a shot from the enemy's batteries coming from p'' would be stopped by the traverse *l*, which thus shelters the defenders on the banquette *k*: whereas, in the single crotchet, the head of the traverse *m* does not protect the defenders on the banquette *o* from a shot coming from q': besides which, the few men that could find a momentary shelter in the nook *b* of the double crotchet would still be exposed to a fire from the parapet s'' of the main-work in its rear.

As each traverse with its passage occupies a portion of the length of the covered-way of about fifty feet, it is necessary to suppress the regular banquette of the covered-way in these places; by which, there is a loss at each traverse of the quantity of musketry fire that could be derived from this space of fifty feet: to obviate which, it has been proposed to support the interior of the glacis at the crotchets by a perpendicular wall of masonry; at the foot of which a narrow step of masonry could be built, to permit the defenders to fire over the glacis: in this case, it may be readily seen by fig. 7, that the single crotchets *e* and *f* are more suited for such a construction than the double crotchets *a b*, *c d*; as men placed behind the latter would be apt to fire upon each other: but in the single crotchets, they would assist in flanking the adjoining lines. This is one of the theoretical improvements that has not yet had the test of practice.

54. It has been recommended by some engineers to make these passages nine feet in the clear, that light artillery might be taken through them in case of need; when the single crotchet would be found more easy to pass than the double: others limit the passage to six feet in the clear, that as much banquette as possible might be given to the glacis.

55. It has been asserted that, in a sudden assault, the assailants, besides forcing themselves into the salient place of arms *z*, would man the crest of the glacis *x x x*, fig. 7, and with spears or lances prevent the defenders retiring by the usual passage; to obviate which it has been proposed to make a passage of six feet, as at *t*, on the side next the counterscarp; and to prevent a chance shot enfilading the covered-way through this opening, an additional thin traverse *u* would have to be added; or, instead of this passage *t* and additional traverse *u*, it has been recommended to insert stone or strong timber corbels *v v* into the revêtement, and by laying planks over them to form a balcony to pass round the traverse, and thus avoid the supposed obstacle at *x x*. These details, however, are not suited for practice, as the spearmen at *x x* ought not to be permitted to have anything beyond a momentary possession of such a position.

56. Lastly, the covered-way being low and fully commanded by all the main works in its rear, it may be even abandoned to a sudden and overpowering attack, in order that the whole fire of the other works may be brought upon the enemy within it: and when it is thus obliged to yield, there is always a hope of regaining possession of it under the fire of the more commanding works.

57. Definition 28 and paragraph 34 state the nature and dimensions of the ravelin; the relief of which is sufficient to permit it to fire over the glacis with ease, and in general it is

only from three to six feet lower than the body of the place: it is therefore well situated for flanking by its fire all the ground on either side of it, and thus effectually defending all approach on the capitals of the bastions, by a close and powerful fire: for suppose a front, as *q b*, fig. 1, without a ravelin, the capitals of the bastions would be flanked only by the fire of light artillery and musketry from the distant faces of the re-entering place of arms 2; an enemy also could establish strong batteries (1, 2, 3) at the re-entering angle of the counterscarp against the flanks of the bastions and the curtain: which position he cannot occupy on the front *r q*, where there is a ravelin, until he has got possession of this formidable work. Its shape then, thus spreading its faces to the rear, covers, in a great measure, the curtain and flanks of the bastions from the fire of an enemy's batteries on the crest of the glacis, as well as from his distant batteries.

58. The ravelin also by its projection makes a re-entering angle at the counterscarp of its ditch on each side, and thus gives the means of forming two re-entering places of arms on one front (as on *r q*); whereas there is but one on a front without a ravelin (as *q b*): therefore, in the former case, the general outline of the covered-way is flanked by a nearer and stronger fire of musketry than in the latter.

59. In a front without a ravelin, as in fig. 1, *b* 4, the bridge of communication leads from the enceinte to the tenaille (5), and thence to the re-entering place of arms; which single line it would not be difficult to enfilade; besides offering to an enemy a much greater probability of a successful entrance by a sudden assault, than on a front where there is a ravelin, in which the line of communication between the enceinte and the covered-way is broken; as seen in fig. 1, front *a r*, by the two bridges 7 and 8, both secured by drawbridges and guards within and without.

60. In some cases Vauban gave flanks to his ravelins, as on the front *r d*, fig. 1 (the flanks are usually parallel to the

capital) : the object of this construction is to force the besieger to capture the ravelin before he attempts to assault the faces of the adjoining bastions; since to do so, without silencing these flanks, would subject the assaulting party to be taken in flank and reverse by a battery of at least four guns : for instance, the batteries in the flank of the ravelin 15 bears upon the whole face of the bastion *r* 14, in flank and in reverse.

61. The ravelin then is a work of great importance, not only from its positive, but also from its relative value, and is indispensable to the efficiency of a front accessible to a regular attack.

62. Definition 31 notices the position and some of the dimensions of the tenaille : this work is of more value from its passive and relative, than for its active properties : its crest (which is determined according to a process detailed in paragraph 117) is usually a few feet higher than the plane of site, that the artillery on the flanks of the bastions may be able to fire over it upon the main-ditch. It is made eight toises thick, that there may be room on it for a regular parapet, with a useful terre-pleine of twelve feet wide in its rear: thus furnished, the tenaille can give a direct fire into the interior of the ravelin, after an enemy has taken it; as also an oblique fire upon the main-ditch and the covered-way: to these, its active properties, it adds the important advantage of hiding nearly all the revêtement of the curtain and flanks of the bastions from the view of the enemy's batteries established on the crest of the glacis; or subsequently in the ravelin after its fall: therefore, according to the principles laid down at the end of paragraph 8, a breach fit to assault cannot be made in these parts of the enceinte, and the revêtement of the face of the bastion alone is sufficiently exposed to have a practicable breach made in it; thus then the enemy must assault that portion of the enceinte behind which the defenders have ample space for making the best defence possible.

63. Again, the mass of the tenaille is no less useful in hiding from the enemy's establishment on the covered-way the

opening or door of a vaulted passage or postern of masonry (9, 10, fig. 14) that communicates from the interior slope of the rampart in the centre of the curtain, to the main-ditch; a postern is also pierced through the tenaille itself, (10, 11, fig. 14; figs. 54 and 55); and a protected passage, the caponniere (definition 34) then leads to the gorge of the ravelin; thus a communication is kept up between the enceinte and the ravelin, a matter of the first importance in giving vigour to the defence of this latter work. Now, if there were no tenaille, as on the front *a* 9, fig. 1, the batteries of attack (11, 12) on the crest of the glacis (or 13 established after the fall of the ravelin) would completely command the mouth of the postern at 10, and prevent any egress or ingress by it, the only passage from and to the interior of the place; a result that would be ruinous to the active defence of the outworks, and which would entirely preclude the formation of troops in the rear of the tenaille, for offensive purposes at the latter part of the siege.

64. On the front *r a*, fig. 1, the main-ditch is supposed to be filled with water, which of course passes round the flanks and the rear of the tenaille; and as the relief of the tenaille is generally from twenty-three feet to twenty-eight feet, its crest would be from fifteen feet to twenty feet above the level of the water, there would therefore be a space of dead ground, or rather of dead water, before the tenaille: this is not however of great consequence, as no force of the enemy could get there without being seen on their way; and no object is to be gained by getting there, for possession of the tenaille would be of no use; nor could this isolated work be kept under the tremendous fire of the flanks and curtain. In a dry ditch the dead ground is rectified by a caponniere (paragraph 65). The tenaille is sometimes formed as seen on the left front of fig. 25, that is, with small faces, flanks, and a curtain: the object of this construction is to obtain a more direct fire into the ditch from the flanks, 2, 3; 4, 5, to aid the flanks of the bastion, 7, 8; 9, 10; the ditch in rear of the tenaille must always be thirty feet wide.

65. A caponniere is placed in a dry ditch for the purposes named in definition 34; for instance, in fig. 1, front 4, 9, there is a single caponniere in the bottom of the ditch of the ravelin to cover the defenders passing from the end of the wall 18 to 19: and there is a double caponniere at the bottom of the main-ditch from the mouth of the postern in the tenaille (16) to the staircases at the foot of the gorge of the ravelin (17). Caponnieres are placed wherever they may be required. When a cunette is used (definition 33), it is flanked by a caponniere.

66. We now come to consider the uses and value to the various parts of the enceinte; the student is referred to paragraphs 25, 26, 27, 28, 37, 39, and 40, for the principles of their construction, and for some of their uses; from which it may be gathered that the bastions are the most important parts of the enceinte from their projection, position, and interior space.

67. The whole of this first enclosure being the last permanent obstacle the enemy has to overcome, it is consequently the most formidable, having a broad ditch before it with scarp revêtements from thirty feet to thirty-five feet in height; massive ramparts and parapets carrying the heaviest artillery, the various lines of which mutually flank each other, and by their height overlook all the works before them.

68. In fig. 1, it may be seen by the position of the faces of the bastions that they fully flank by their fire all the ground before the faces of the ravelins, and all the approaches by its capital to its flanked angle or weak point: the ditch of the ravelin is also defended by the fire of those portions of the faces of the bastions that look upon it; and these must be silenced ere the enemy can pass the ditch thus flanked to assault the ravelin.

69. The flanks of the bastion can carry batteries of six or seven pieces of artillery each, to defend the main ditch; and as it has been already shown that the faces of the bastions are the only parts of the enceinte in which the assailant can make practicable breaches, (paragraph 62) it is quite necessary that the ditches by which these breaches can be reached, should be

fully swept by the fire of the flanks; and this is the case; for in fig. 1, front $r\ q$, the fire of the flank $p\ o$ sweeps the whole of the ditch $z\ k$, before the face of the bastion $m\ r$: now in a regular attack, the passage of the main-ditch cannot be effected under the fire of so strong a battery, which has to be silenced before the attempt be made.

70. The curtain may be said to have more a passive than an active defence; it closes in the body of the place by joining the bastions to each other, and it overlooks the works before it; into which it can pour a strong fire after their fall into the hands of the assailant: as it has only a command of observation over the ravelin, (definition 21) its embrasures must be oblique to fire into the covered-way, or upon the country beyond it.

71. Thus, in the enceinte, the faces of the bastions may be said to have the most active duties to perform; the flanks are for a specific object, viz. the defence of the-main ditch; and the curtain is nearly a passive barrier till the end of the siege, when its fire tells strongly on the works before it.

CHAPTER IV.

Observations on some of those parts of plan drawing that are, in general, difficult for a pupil to understand: Communications.

72. In representing the works of a fortress, a plan and profile become necessary; the former, to show the horizontal lengths and breadths; and the latter, the vertical heights and depths, of the works and ditches: for instance, let a simple traverse or parapet be considered; of which fig. 8 is a plan, and fig. 9 a profile; the horizontal breadths are marked on the ground line $a\ b$, as well as the vertical heights of the different parts of the mass, from the same line: but the length and position of the traverse cannot be seen by the profile (fig. 9); for them a plan (fig. 8) is necessary.

73. The extremities of a mass of earth, of common tenacity, shaped as in fig. 8, will not stand perpendicularly; that is, the earth on the lines *c d* and *e f* would not remain upright, but would seek a slope *e h k m o f* that would stand without wearing away.

74. A mass of common earth, oblong shaped, as fig. 10, *r q s t*, could only be made to stand without falling or wearing away, when it has a base *q x* equal to its height *x u;* therefore, to stand firmly, it must be shaped as *q u v t:* and, in applying this principle to the parapet in fig. 8, the base *i k* of the slope at the extremity would equal the height of the crest, that is, seven feet and a half; *g k*=five feet; *l m* and *n o* each three feet and a half; and the same dimensions would be required at the other end *c d:* so that, if the whole line, *i p*, of the crest be thirty feet; the real crest *k r* would only be fifteen feet; and thus half the utility of the parapet would be lost by the great natural slopes necessary for the ends of the traverses; since the musketry defenders could only be ranged on the banquette from *s* to *t*, to fire over the crest *k r:* besides, if traverses were thus cut away, and had such narrow tops, (as *k r*), they would not fully answer their purpose of shielding the covered-way from an enfilading fire.

75. Now it is plain that this could be easily rectified by building perpendicular walls of sufficient stability to support these extremities of the parapets; and, by this means, the full use of the whole crest *i p* and its banquette *n u* would be available: but masonry to support all the extremities of traverses, the steep interior slopes of parapets, the cheeks of embrasures, &c. are objectionable for two reasons; the first is the increased expenditure thereby, of the most expensive material used in the construction of a fortress; and the second is the destructive effects of the splinters detached from masonry, by the shot from the attacking batteries striking it; which would assuredly be the case, in the event of the interior slopes of parapets and the cheeks of embrasures being lined with masonry.

76. It is therefore customary in permanent works to make use of the description of revêtements common in field works, for

supporting the parts first spoken of, that the serious objections to masonry may be obviated; these temporary revêtements are of *turf, gabions, fascines, and sand-bags.*

77. The *turf* or *sod-work* is cut from good clayey meadow land; each turf is from fifteen to eighteen inches long and three or four inches thick; they are built up like brick-work as headers and stretchers, and strongly picketted down: this support is sufficient in a parapet of six or eight feet high, if it has a base of one third or one fourth of the height. Sod-work, however, requires to be carefully cut and laid, and often needs repair.

78. Gabions are cylindrical baskets open at both ends, from twenty to twenty-four inches in diameter, and from three to four feet high; they are placed upright or with a very small slope, and, when filled with earth, they resist the pressure of the mass of the parapet against them, and form a very good steep support; they are quickly and readily laid, are much used in field works, but are, of course, perishable.

79. Fascines are cylindrical faggots of strong brushwood from six to eighteen feet in length, and nine inches in diameter; they are laid lengthways as the parapet is built up, and are well picketted down; they can be built up with a slope of one third or one fourth of the height for a parapet six or eight feet high; they form an excellent revêtement, are readily laid, and much in use.

80. Sand-bags are always kept in store in bales of two hundred bags; when filled with sand, they are two feet three inches long, one foot broad, and seven inches thick; they are built up like brickwork, having a base of one third or one fourth of the height of the parapet; they form a very good revêtement for a short time, and from being so handy, are greatly used in sieges; but they are very perishable.

81. If, to the extremities of a traverse, such as is represented in fig. 8, a good field revêtement be applied, having a base of one fourth of its height, the space *f e h k m o* would be

greatly diminished; and it would assume the appearance of the dotted profile above the line *dc;* then, instead of the crest *hr* being only fifteen feet, it would be twenty-six feet three inches; and thus almost the full use of the defensive properties of the traverses would be insured: and the extremities of works, thus supported by sloping revêtements, must always have the distorted appearance represented in the plans.

In order to aid the defenders to pass round the crotchets of the glacis with the greatest possible ease, it is customary to round off the angles of earthen slopes at the outer extremity of the traverses, as in fig. 10, *zz*; and as seen in the traverses *m h*, fig. 7. The angles of the slopes of the banquettes of the covered-way are also rounded off at the crotchets, for the same reason, as seen in fig. 7.

82. Vauban's revêtement walls of masonry have all a slope in front of one fifth part of their height, and are represented in plan and profile as seen in figs. 4 and 3; where *fg* shows the horizontal width of the slope of the wall: now suppose this to be the case in fig. 7, in the counterscarp revêtement *np*, it is customary to build the wall up in continuation of its slope to support the extremities of the traverses, so that the wall is higher (by the height and shape of the end of the traverse) at the part *rs* than it is elsewhere; for the crest *s* of the traverse *m* is seven feet and a half higher than the terre-pleine *z*; and $7\frac{1}{2} \div 5 = 1\frac{1}{2}$ which, being added to the width *np*, gives a breadth *sq* of five feet eleven inches; and the other parts of the profile are obtained in like manner.

83. Thus, all the extremities of the faces of the ravelins and of the tenailles are supported by their revêtement walls, built up in continuation of their slopes; and which is shown by their irregular appearance in their plans, as in fig. 14: and the interior slope of the glacis, as well as that of the other parapets; also of the ends of the traverses next the glacis; the cheeks of the embrasures, the extremities of caponnieres, &c., are supported by some of the field modes of revêting, mentioned in paragraphs 76, &c.

84. But where the revêtements are perpendicular, as in figs. 210 and 211, the extremities of the works, as well as of the traverses, are simply represented by a straight line; and sometimes even in sloping walls, the extremities of the traverses and other works are finished by perpendicular walls, as are seen in fig. 7, traverses l and g. And, it is customary also, in drawing plans on a small scale, to suppress the slopes that have very small bases; such as the interior slopes of parapets, the ends of traverses, &c.

85. The expense and labour of renewing the field revêtements for the interior slopes of parapets, and to the cheeks of embrasures, is very small; as they are not formed till a siege is apprehended, the interior slopes and banquettes remaining in a rough state; and the only embrasures, permanently open, are those intended for the defence of ditches, as seen in the right front of fig. 14.

86. In the details of the construction of staircases there is some difficulty at first, especially where the revêtements are sloping as in Vauban's systems; for example, in fig. 7 the top and bottom of the revêtement wall is shown at the rounding of the counterscarp by the arcs nr, $p, p'p'', p$; and a flight of steps ascending in the masonry from the bottom of the ditch $p'p''$ to the top of the wall nr, must assume a form suited to this curve. To construct these staircases, a distance of six feet is laid off on the lower arc, on each side of the capital, to $p'p''$, so as to form a platform or landing place at the foot of the steps: the distances $p'n$, $p''r$ depend upon the height of the revêtement, and on the spare space that there may be between the traverses l and m: when this space is restricted, and the revêtement is tolerably high, the staircases must necessarily be steep; but when there is sufficient room, it is desirable to have the general slope of stairs as easy as possible: the distance $p'n$, or $p''r$ is usually about thirty feet; the points $p''r$ being fixed, they become centres, on which to describe arcs intersecting each other at s', with a radius equal to the width of the ditch: from s', as a centre, with the same radius describe the arc $p''r$; and a con-

centric one beyond it, with the radius $s r'$; the space $r r'$ being usually six feet, which is the width of the stairs; after performing a like operation on the side $p' n$; then, from the salient angle of the cordon of the escarp, describe the arc $n' r'$ which is the top of a wall that runs down to meet the inner edge of the steps; each successive step between p'' and r should be directed to the point s. An iron rail sometimes runs on the outer edge of the steps from p'' to r, and an iron fence gate closes either the top or the bottom of the staircase.

87. At the re-entering angles of the counterscarps, the principle of construction is the same for the staircases as detailed in the last paragraph; but as the tracing is generally in right lines, they are more easily laid down on paper: for instance, in fig. 11, where abc represents the re-entering angle; ad the slope of the counterscarp wall; be = nine feet: ei, the length of the general slope of the staircase, is thirty-six feet: io = six feet, the width of the steps: lo (the top of the wall that slopes down to meet the inner edge of the steps) is parallel to the cordon of the revêtement.

88. With perpendicular revêtements the staircases are much more simple in their tracing, as they merely occupy recesses in the gorges of the works, or in the salient and re-entering places of arms, six feet in depth, and of as easy a slope as possible.

When a plan is drawn on a small scale, where it is usual to suppress the slopes of the revêtements, the staircases are represented as in perpendicular walls.

89. Ramps are gentle slopes of earth, constructed along the interior slopes of ramparts, to facilitate the passage of artillery, &c., from the interior to the terre-pleine of a work. To construct a ramp, let bac, fig. 12, show the original tracing of the rampart; bk being the breadth of the interior slope; and let b be fourteen feet higher than k (as is the case in fig. 3, where the interior slope has a base and a height of fourteen feet each): lay off eight toises from a to d, and, with a radius of eighteen toises from d as a centre, cut the foot of the interior slope in e; join ed, and at each extremity raise perpendiculars to it, ef and dh; draw fg

parallel to ed at three toises; a corresponding operation is to be conducted on the other side to form mo: then, from h as a centre, describe the arc gl and decrease the radius hg by three toises to get hi; and describe the arc ip, to which fi and op are drawn as tangents: de is one hundred and eight feet, the length of the ramp; dg, its breadth, is eighteen feet: the descent begins at dg, and the slope which runs gently to ef is, in this figure, in the proportion of 1·55 inches to a foot.

90. In plan drawing it is customary to represent all the masonry work in red lines, and the earthen works in black; the cordon or master-line of the escarp is a thick red line, and all the crests of the parapets are in thick black lines. The tint of Indian ink for shading should be very light, and all slopes shaded down, from top to bottom, with a water brush. To ornament the plan, the rays of light are supposed to enter from the upper left hand corner of the paper; and all slopes that face it are but lightly shaded, while those that recede from it are more strongly so. Dry ditches have usually a light flat tint of burnt sienna or umber; and wet ditches a light flat tint of blue.

In a profile, the earthen works are shown by a tint of umber or sienna; the masonry by a light flat shade of lake: to finish the plan, there is a thick red line on the side of the masonry, furthest from the light.

Communications.

91. The communications between the interior of the place and the country, between the various works, and those to facilitate the passage of artillery, &c. from one part to another, may be divided into

1. Gateways.
2. Bridges.
3. Posterns.
4. Caponnieres.
5. Staircases.
6. Ramps.

Of these the two first may be considered as especially made for the convenience and use of the inhabitants in their intercourse with the country; and the four last more particularly for the use of the garrison.

92. Of the former there should be as few as possible, since they entail extra duties on the garrison, requiring constant watching and repair. In places of a small size, and, if possible, in every place, two main passages should be made to suffice; for instance, in fig. 1, the opposite fronts *r a* and *b* 4 have regular bridges of timber across the ditches and passages cut through the ramparts and glacis, which lead to the main roads without: the rampart in the centre of the curtain is therefore left open, and supported on each side by masonry, to form a road sufficiently wide for the passage of carriages, waggons, &c.; that is, from eighteen to twenty-four feet wide; this passes underneath an archway in the scarp revêtement, and leads over a bridge, on the same level, to the tenaille: the passage is continued through the parapet of the tenaille, over a bridge connecting the re-entering angle of the tenaille with the gorge of the ravelin; in like manner, it proceeds through the ravelin, its rampart, and across its ditch by a bridge, to the covered-way: a winding road is cut through the glacis, (to prevent its being enfiladed), which leads to the main roads without; as seen in fig. 1, front *r a*. Here also it may be observed that this road, and the bridges it crosses, are fully defended; the main bridge leading from the body of the place to the ravelin is placed between the batteries on the flanks of the two adjoining bastions; as well as exposed to the fire of the tenaille and curtain: the continuation of the road through the ravelin and across the bridge of its ditch, can be both enfiladed and flanked from the different parts of the enceinte that command it; in short, this road of communication is better protected in this situation than it could be if placed in any other part of the works.

93. The bridges are always broken by drawbridges which can be raised on a moment of emergency; and are usually drawn up every night by order of the governor of the place: guards

are necessary in the covered-way, ravelin, and curtain, to protect and watch the bridges; and every precaution is constantly used to prevent an enemy getting any access to these passages, either by force or stratagem.

94. It has been usual to have high ornamented gateways leading to the bridges in the scarp revêtements through which the road leads; but they are disapproved of, as being higher than the revêtements, their masonry is seen above the crest of the glacis, and they thus point out to an enemy the exact position of the bridges, and assist him in destroying the communications from his distant batteries: besides which, these great gateways occupy thirty or forty feet in the length of the revêtement, and prevent that portion of the parapet from furnishing any fire.

95. *Posterns* are vaulted passages of masonry constructed underneath the mass of the rampart, to communicate from the interior of a work into the ditch before it, as in fig. 54: in a dry ditch the door at the mouth of the postern is about six feet from the level of the ditch, and the defenders pass up and down by temporary wooden steps which are removed at pleasure; so that, if an enemy gets into the ditch, and is so powerful that the defenders must retire by the posterns, the wooden steps can be drawn into the mouth of the postern and the door shut, which, being loop-holed, permits a fire of musketry to be brought upon the assailants.

96. Posterns are usually from five to nine feet wide, and from six to seven feet high at the crown of the arch; they are closed at each extremity by doors, within which are recesses of masonry for stores, &c. (fig. 54): although posterns are only intended as secure covered passages for men to pass from the inside to the outside of a work, yet when nine feet wide they will admit of light artillery being taken through them and passed into the ditch on inclined planks; and even when narrower, guns and their carriages can be passed through when taken to pieces.

97. In wet ditches, the posterns lead from the interior of the rampart to the level of the bridge that crosses the ditch; or, if the ditch be crossed by boats, to the level of the water.

98. Posterns are made on the first construction of the fortress wherever they may be required; the interior earthen slope of the rampart is suppressed, and masonry supports the sides of the passage leading into the postern; the vault of which passes through the whole thickness of the rampart, as seen in fig. 54; the masonry being, of course, made strong enough to resist the pressure that it has to support both laterally and vertically.

99. In a regular front, as fig. 14, the postern in the centre of the curtain is indicated by the dotted cross lines, issuing out into the main-ditch (at 10) behind the tenaille where the defenders are in perfect security, they proceed through the mass of the tenaille by the postern shown in its centre by the dotted cross lines 11, and then pass through the main-ditch covered by the caponniere; either to ascend by the staircases at the gorge of the ravelin, or to proceed by the passages 8, 8 along the foot of the demi-gorge walls of the ravelin to the staircases leading into the re-entering places of arms: figs. 54 and 55 is a section taken on the line 9, 10, 11, of fig. 14. It was through passages of this kind that sallies issued in the old fortifications, which obtained for them the name of *sally-ports*, by which they are still sometimes called.

100. Definition 34, paragraphs 64 and 65, give every necessary detail respecting caponnieres.

101. On staircases very little need now be said, as their situation, tracing, and dimensions, are laid down in paragraphs 86, 87, and 88; they should always have a sufficient slope to make it easy to pass up and down quickly. Staircases are, in many cases, carried down within six feet of the bottom of the ditch, and temporary wooden steps are used to reach the bottom: these are removed at pleasure to render it difficult for an enemy to enter a work by the gorge should he succeed in getting into

the ditch. Staircases are objected to from the possibility of their being greatly injured or destroyed during a siege by shells falling, and bursting upon them; which likewise causes many splinters: and it is difficult to repair or restore the communication during the arduous occupations of a siege.

102. Ramps, being long, broad earthen slopes, as described in paragraph 89, are most useful and convenient communications; easily repaired if injured by shells during a siege.

103. As, in the interior slopes of ramparts, ramps are for the use and transport of artillery, &c., they should be sufficiently gentle and broad to permit the guns to be run up and down with ease and safety: and as this labour augments with an increase of height, ramps in high ramparts are proportionally longer than in low ramparts. Theoretical writers average the length of ramps at about ten times their height.

104. As the ramparts in the outworks are lower than those of the enceinte; and as the guns on the former are usually of a less calibre than on the latter, their ramps are neither so long nor so broad as those of the body of the place.

105. Ramps are made at the gorges of the ramparts of full bastions; in the flanks of empty bastions, and in the gorges of the ramparts of ravelins as seen in fig. 14; they are also made in the crest of the glacis for the exit of sorties; their tracing is such as to prevent their being enfiladed as in fig. 14; they are usually thirty feet long, twelve feet broad, and are closed by barrier gates of palisades.

106. Although the interior slopes of ramparts can be ascended and descended as they are only natural slopes of 45°, yet they are too steep for easy or common communications; and staircases are sometimes made in the centres of the curtains (as in fig. 14,) to assist in case of need; but in general the ramps are sufficient for all needful purposes.

107. It has been recommended to substitute ramps for staircases wherever it can be done; and a sufficient space for their construction is, in general, the only obstacle to its being done:

for instance, in the modern system fig. 210, where the counterscarp of the redoubts of the ravelins and of re-entering places of arms admit of the construction, ramps are preferred to staircases.

108. Lastly; Safe and assured communications between the different works, and especially between the enceinte and the outworks, are of the first importance. It is absolutely necessary for the good defence of a work that there should be the means of succouring it by reinforcements through safe and convenient passages; of relieving the troops on duty; of withdrawing them in safety when they can resist no longer, &c.: and this can only be done by a sufficient number of the communications described above: they are therefore indispensable; not only as they affect the actual means of resistance, but also from the influence they have on the moral feeling of the soldier; who performs his duty with a much greater degree of confidence and cheerfulness when assured of aid, or of a safe retreat if overpowered.

CHAPTER V.

On relief and command; on ditches.

109. From definition 10, it follows, that however important it may be to dispose the tracing of the works of a fortification so that their reciprocal defence may not interfere with their general effect upon the country; it is of no less importance to determine the relief which provides for that elevation of the works that is best suited for ensuring the full effect of their fire for all the purposes desired.

110. The relief is generally determined by means of profiles (definition 19); and it is said that a place is well *profiled* when the works cover and defend each other without injury to their particular command over the country.

111. In considering this subject, the pupil is reminded that the works are still supposed to be constructed on a horizontal

plane; the intricacies of construction, in cases of irregular sites or the neighbourhood of hills, are explained from paragraph 329 to 351.

112. In profiling the works of a fortress, the following principles should be kept in view.

Firstly. That all parts of the surrounding country, within the range of the artillery and musketry of the defences, should be seen and exposed to their fire.

Secondly. That an enemy from without should not be able to see any part of the works.

Thirdly. That no part of the revêtements should be seen by an enemy till he has worked up to the crest of the glacis.

Fourthly. That all the works progressively increase in height as they approach the body of the place.

The first principle has been established in order that an enemy may not get cover from natural obstacles within range of the defensive weapons; to oblige him to begin the works for the siege at a considerable distance; and that he may be fully exposed to the fire of the place as he progresses towards it. The second principle shows that an enemy must not have it in his power, while yet at a distance, to drive the defenders from their works: its application to works, within the range of heights which an enemy can possess, forms the subject of defilement. The third principle is to oblige the enemy to bring his battering train of guns to the crest of the glacis; as, till then, he cannot see the scarp revêtements to form breaches fit for assault. The fourth shows that when an enemy gets possession of the works in succession, beginning with the outermost and lowest, those that remain, being more elevated, can bring a fire upon the captured works; either to drive an enemy out of, or to disturb his lodgment in, them. The tenaille is an exception to this rule, for reasons stated in paragraphs 62 and 117.

113. In the application of these leading principles, they must be subservient to the promotion of the great objects of the tracing and the uses of the works, as stated from paragraph 45

to 71; and also to ensure the full effect of the defensive weapons.

114. In the first place: to determine the proper command for the enceinte over the country; let *s s*′, fig. 14, be about the position of the enemy's third parallel, (or his last trench ere he begins to push his works up the glacis): and let a section on the line *n r s* be represented by fig. 15; the horizontal distances in both figures being represented by the same letters *n r s:* it is required to know how high the gun at *n*, fig. 14, should be in embrasure, to permit it to fire upon the enemy's trenches at *s*, without injury to the musketry defenders on the covered-way at *r*. The horizontal distances in the two fig. 14 and 15 are as follows: *sr*=three hundred feet; *sn*=four hundred and fifty feet: the crest of the glacis in fig. 15 is eight feet high (that is *rz*=eight feet) and if the line *y q s* be supposed to represent the track of a shot fired from the gun *y* at the trench *s*, and to pass clear of the crest *z* of the glacis by four feet; then *r q*=twelve feet. Now there are two similar right angled triangles in fig. 15, viz. *s r q* and *s n y*, of which the two bases and one perpendicular are given, to find the remaining perpendicular *n y*, which is done by the following simple proportion:

s r : *s n* : : *r q* : *n y;* or 300-ft. : 450-ft. : : 12-ft. : 18-ft.

but a gun in embrasure is at least four feet and a half below the crest; therefore, to obtain the full command of the work, four feet and a half must be added to the eighteen feet found, which gives twenty-two feet and a half for the command of the enceinte over the country; and fourteen feet and a half, for its command over the crest of the glacis. Thus is the command of the enceinte determined: but it is plain that if the tracing varies from that here laid down, the result of the proportion will do so likewise; if, for instance, the ditch be wider than fifteen toises, the base of the triangle *s n y* fig. 15 will be greater, which will augment the second term of the proportion and produce a greater result; or, in any words the enceinte will be higher. A covered-way wider than thirty feet would also increase the height of the enceinte:

and if the crest of the glacis were made higher than here stated, so as to increase the third term of the proportion, the result would still increase the height of the enceinte. A tracing that would produce the converse of the above, would, of course, permit the enceinte to be made lower. It is now easily seen why the ravelin can be made lower than the enceinte and still maintain a sufficient height over the crest of the glacis to act upon the enemy's works; since, by the narrowness of the ditch of the ravelin, the distance between its crest and that of the glacis is thirty or forty feet less than between the crests of the faces of the bastion and glacis: for the command of the ravelin is determined in a like manner to that detailed above for the enceinte: and, if the artillery on the faces of the bastions and ravelins can thus clear the crest of the glacis when their fire is directed upon the nearest trenches, they can of course act upon all beyond them; and, in proportion as the object fired at is distant, the track of the shot will be more and more above the crest of the glacis.

115. Although the foregoing arrangement is drawn from Vauban's works and the opinions of those who have followed him, yet it is not to be expected that the musketry defenders can man the whole of the banquette of the covered-way, and be in security from the shot of their own guns, that would absolutely graze their heads when firing at the enemy's third parallel. To permit both parties to act freely by their fire upon the foot of the glacis, the crest of the advanced work should be at least eight feet below the track of the shot flying over it, that the defenders behind it may be quite safe: if this were carried into effect, it would alter the third term of the proportion, at fig. 15, to sixteen feet; and produce the enormous remblai (definition 36) at twenty-eight feet and a half for the command of the enceinte over the country; a result, too, that would greatly interfere with many of the principles of tracing already detailed; (as for example, with that of the length of the curtain at paragraph 26). Nevertheless, if such portions of the banquette of the covered-way, as do not immediately lie under the range of the artillery

on the main works, (such as the places of arms), be furnished with a musketry fire, and if the service of the guns be carefully carried on, these two arms can act thus partially and efficiently together upon all the enemy's approaches.

116. It would therefore appear from the last paragraph, that as the artillery and musketry cannot always act simultaneously, and as, on some occasions, it becomes necessary for the musketry to descend from their banquettes and lie down in the covered-way, that it is possible to do with such a height of enceinte as will permit the guns in embrasure just to clear the top of the palisades of the covered-way, when the shot is directed at the enemy's third parallel: and some writers recommend this fire as being more destructive, as grazing along the surface of the ground; while shot fired from higher works, being more plunging, bury themselves in the spot they strike, and do no farther damage: advocates for the *grazing fire* would limit the command of the enceinte to seventeen feet over the country, and nine or ten feet over the crest of the glacis. More generally, however, a *plunging fire* is preferred; since a shot fired upon the enemy's trenches from a height, cuts more deeply through the crests of his parapets and obliges him to heighten them or deepen his trenches in the rear, in order to obtain sufficient cover; the loss and delay of which is of more consequence to the defenders than the imagined destruction of a grazing fire from a work a few feet lower: besides, low works are more easily enfiladed than high ones: those who prefer the latter recommend the crest of the enceinte to be made twenty-five feet above the country. This would, however, greatly increase the remblai, and interfere with the principles of tracing already laid down, without giving a corresponding advantage for such sacrifices. A medium, therefore, of twenty-two feet is about the standard followed by Vauban and other engineers of experience, as it permits both the musketry on the covered-way, and artillery batteries in its rear, to act together in a great measure.

Circumstances, however, may perfectly justify a departure from this rule; for example, a command of seventeen feet for the enceinte of a small front of one hundred and twenty toises would be much more suitable, and harmonize much more with the tracing, than a command of twenty-two feet.

117. At the end of paragraph 112, it is said that the tenaille is an exception to the fourth principle therein laid down; that is, all the works of a regular front progressively increase in height as they approach the enceinte, except the tenaille. The pupil must here refer to paragraphs 62, 63, and 64, and be acquainted with the uses of the tenaille, ere he can pursue the following principle for regulating its relief.

When the enemy gains the crest of the glacis, and there establishes his counter and breaching batteries, he will have one on the space *f i*, fig. 14, which will command the ditch of the ravelin immediately before it, and through which opening he can form a breach in the face of the bastion near the shoulder angle at *k k*; and, as there is no other part of the enceinte, save the faces, of the bastions that can have practicable breaches made in them, that made at *k k* will be the nearest to the flank *m* that can be formed; and if the battery on *m* can bear on the bottom of the ditch before *k*, it will, of course, command the main-ditch all the way up from *k* to the rounding of the counterscarp. Now the relief of the tenaille must not be permitted to interfere with this fire from the flank; in other words, a shot fired from a gun (*m*) in embrasure must clear the crest of the tenaille by four feet.

In this tracing (fig. 14) the horizontal distance *k m*=five hundred and four feet, and *k l*=three hundred and forty-eight feet; the vertical height of a gun at *m* above the level of the main-ditch is forty feet; (for here the crest of the enceinte is twenty-two feet and a half above, and the bottom of the ditch is twenty-two feet below, the ground line, as seen in fig. 13, making a total relief of forty-four feet and a half for the enceinte; from which take four feet and a half for the axis of the gun in embrasure at *m* below the crest). Let these distances be laid down as in fig. 15, *B*, in the right angled similar triangles $km\acute{m}$ and $kl\acute{l}$; $m\acute{m}$ being the vertical height of forty feet, and the horizontal distances agreeing with the corresponding letters in fig. 14: the line $\acute{m}k$ will represent the flight of a shot fired from the gun *m* to the bottom of the ditch *k*; and $\acute{l}$ is the point in this flight directly over the tenaille: it is then required to find the height $l\acute{l}$, and from it to deduct four feet, for the relief of the tenaille at this spot; this is done by the following proportion: $km : kl : : m\acute{m} : l\acute{l}$; or $504 : 348 : : 40 : 27\frac{1}{2} - 4 = 23\frac{1}{2}$; or *lx* the relief of the tenaille.

118. In applying the observations at the end of paragraph 114 to the position of the flank and of the tenaille, it is seen by fig. 14 that the crest of the latter is continually receding from that of the former, on the line *mk*: therefore, although the four guns from *m* to the shoulder angle have a full clear view of the bottom of the ditch at $k\acute{k}$, the other four guns from *m* to the curtain angle are masked to a certain degree by the left face of the tenaille; and it is only by directing their fire over its right face that they can strike the bottom of the main-ditch near the required part: nevertheless, when it is considered that the breach is a slope of rubbish from the bottom of the ditch upwards; and that guns on the flank *m* can be depressed lower than is illustrated by fig. 15, *B*, so as to graze the crest of the tenaille, (as the dotted line $\acute{m}x$, fig. 15, *B*, indicates), it shows that this mode of determining the relief of the tenaille ensures the full action of the flank of the bastion upon the main-ditch before the face of the next bastion. The construction of the tenaille represented on the left front of fig. 25 is more favourable for the guns on the flanks of the bastions to see into the ditch than the plain tenaille in fig. 14.

119. In paragraph 64 it is noticed that, in wet ditches, there would be a dead space before the angle of the tenaille; now, by the foregoing observations, it would appear that the two or three guns near the shoulder of the flank *m*, fig. 14, would be enabled to plunge their fire into nearly the whole of this space;

and both flanks thus acting, the undefended part would be reduced to a very small space.

120. It appears from paragraph 117, that although the relief of the tenaille is fixed at twenty-three feet and a half, when the tracing is as in fig. 14, and the relief of the enceinte is forty-four feet and a half; yet, a different tracing or relief would immediately alter the proportions of the illustrative fig. 15, *B*, and produce a different result. In the relief is included the depth of the ditch, and every change in it would affect the height $m\acute{m}$ of fig. 15, *B*; as would also a ditch permanently filled with water: for example; if the ditch in fig. 14 had eight feet depth of water, its surface would be more exposed to the fire of the guns upon the flank m than the bottom of the same ditch would be when drained of water: in such a case, the horizontal distances in fig. 15, *B* would still remain the same, but the vertical height $m\acute{m}$ would be less by eight feet; the proportion would then be as

$$504 : 348 : : 31\tfrac{1}{2} : 21\tfrac{3}{4} - 4 = 17\tfrac{3}{4}\text{-ft.}$$

for the height of the tenaille above the surface of the water; and if to this be added the eight feet below the water line, there will be a total relief of twenty-five feet and three quarters for the tenaille, which exceeds that found at paragraph 117 in the same ditch, when dry, by two feet and a quarter. Hence shallow and wet ditches allow the tenaille to be higher than deep and dry ditches.

The tenaille with flanks, as seen on the left front of fig. 25, would, in most cases, give a greater result for the relief of this work; which would be of advantage in covering the revêtements of the enceinte more completely from the enemy's view. (Paragraph 62).

121. Such other parts of this subject as are not here particularly specified, are treated of elsewhere under more suitable heads; the relief of works, for example, involves in it the height of revêtements, but it is considered more proper to place every thing on the subject of revêtements under a distinct head.

On Ditches.

122. When the soil in which the ditches are excavated, is of a nature that is suited for the construction of the ramparts and parapets; the general capacity of the ditches will then depend upon the quantity of earth required for these defensive masses. And in the first instance, to suppose that the soil is of this nature, will be the simplest way of estimating the dimensions proper for ditches.

123. The quantity of earth required, can be procured, either by making the ditches broad and shallow, or narrow and deep: and to examine how far these two modes affect the principles of relief and tracing already laid down, let fig. 14 represent Vauban's first system: and suppose that the main-ditch, instead of being of the width and depth hitherto named, furnished the same quantity of soil by being made broader and shallower; for instance, let the breadth be increased at the rounding of the counterscarp to twenty toises; and for the soil thus obtained, let there be a corresponding lessening of the depth; suppose it to be eighteen instead of twenty-two feet deep. The first effect of this would be to lessen the height of the revêtements by four feet; which would make the scarp walls of the enceinte and ravelin, twenty-six instead of thirty feet high; and therefore render them more liable to be carried by escalade on a sudden assault, (paragraph 178).

124. The second effect would be to render the enemy's lodgment on the crest of the glacis more formidable, as it would give him more space (*a b* fig. 14) for the establishment of his counterbatteries against the opposite flanks of the bastions; and render it more easy for him to overpower them (paragragh 25). The third effect is to remove the crest of the glacis farther from the crest of the enceinte, and thereby (according to the principle of relief laid down in paragraph 114), to cause an increased command for the latter over the former, which in the construction,

would entail the expenditure of time, soil, and labour. These three effects are so many arguments against widening the ditch, and giving it less depth; besides which, shallow ditches ensure to the enemy's breaching batteries on the crest of the glacis, a full view of the whole scarp revêtement, even to its foot (paragraph 8); and lastly, if the main-ditch be of a less depth than twenty-two feet below the plane of site, there will be no necessity for making the curtain seventy-three toises long (paragraph 26); and, if shortened to the length required for the proper defence of the ditch, the flanks of the bastions (already too short for a wide ditch) become still shorter; the faces of the bastions longer; and a total change may be effected in the tracing, to its great prejudice.

125. One advantage alone is gained by widening the ditch, which is, that it increases the labour of one of the enemy's last operations in the attack, that of constructing a passage across it, which, in wet ditches, is an arduous and toilsome work; and hence it is that it is recommended to make wet wider than dry ditches.

126. Now the effect of a contrary proceeding, viz. that of obtaining the earth required, by making the ditch deeper and narrower than the dimensions hitherto laid down, is also to interfere with the principles of construction detailed in the foregoing part of this work; although the evils resulting from it, (when not carried too far) are not so prejudicial to the defences, as in the case of broad and shallow ditches: for the effects are, of course, converse: in the first place, the revêtements are heightened and thereby rendered more difficult of access: the space on the crest of the glacis for the establishment of the enemy's counterbattery against the flanks of the bastions is more restricted; and it may be even necesssary for him to descend into the covered-way and to construct his breaching batteries there, that he may see the revêtements sufficiently low down to make a breach, as from the crest of the glacis he may not be able to do so: this will greatly augment his labour and occupy his

time (paragraph 50): but although these are positive advantages arising from deepening the ditch, yet in order that a deep main-ditch may be properly flanked, the curtain must be increased in length, which immediately affects the flanks, making them longer, and shortening the faces of the bastions: this would entirely interfere with the tracing which, as has been shown, is most suited to the enceinte; it would affect the shape of the ravelin by making it spread more to the rear: and in the relief, it would permit the command of the enceinte and of the ravelin over the covered-way, to be less: the relief of the tenaille is always affected by the depth of the ditch (paragraph 120): and lastly, in a narrow ditch the rubbish that falls from the formation of a breach would stretch across the bottom of it and form a rough parapet in a dry ditch, or a rough causeway in a wet ditch; which in either case would greatly assist the besieger: to prevent this last evil, it is a rule that the ditch is always to have a width of at least once and half the height of the work.

127. From the above sketch of the effects of altering the dimensions of ditches on a regular front, it appears that less evil would accrue to the defences by ditches being made rather deep and narrow than the reverse: but although this applies in common cases, it may be impossible to adhere to the desired medium between them, under the circumstances of rocky, swampy, or sandy soils; the materials excavated from which are not only unfit to enter into the construction of ramparts and parapets; but the ground itself requires great labour and expense to work in. Yet however bad the soil may be, it is consolidated by a careful construction and by time, while the light parapets and trenches of the besieger are worked under every disadvantage in such soils; and exposed to a fire while under construction.

128. It is not here meant that deep broad ditches are not more formidable obstacles for the assailant to overcome than the moderate ones spoken of in a regular front on a horizontal plane; but however deep and broad a ditch may be, it should be perfectly flanked, that the enemy's miner may not be able to attach himself

to the walls and destroy them by the explosion of mines; and, in no case, should the general good arrangement of the works be sacrificed to obtain a formidable ditch.

129. The next point to enter upon is the kind of ditch best suited for defence: that is, the consideration of wet ditches, dry ditches, or those, that by well managed currents of water, can be made wet or dry at pleasure.

130. If a ditch be permanently wet it can only be crossed by bridges or boats; and so long as an enemy is at a distance the communication between the place and the outworks can be kept up with tolerable ease and security; but from the moment that he establishes himself on the crest of the glacis, his batteries will command all the ditches; the bridges are swept away by his fire; and every attempt to cross must be under his view by day, or within his hearing by night; thus the defenders are deprived of the means of succouring the outworks in the time of need; and the consequent effects upon their defence are so prejudicial, (paragraph 107) that some engineers object to permanently wet ditches, except in swampy ground (where it cannot well be avoided), or when a fortress from having low or defective revêtements, which may offer an inducement to the enterprise of an enemy to attempt to carry it by surprise and escalade; more particularly if the garrison be inefficient either from the quality or number of the troops; in this case a wet ditch serves to secure the place from a coup-de-main. Wet ditches also augment the labour of the besiegers in constructing bridges or causeways across them at the end of the siege, to connect the breaches to the counterscarps.

131. If the ditches of a fortress be permanently dry, then the important object of a safe communication between the enceinte and the outworks, is secured by means of posterns and caponnieres (paragraph 94 to 99 and 108); which gives vigour to the defence and keeps the enemy from the main enclosure as long as possible.

132. If the situation of the fortress admits of the ditches being filled with water at pleasure, there is no doubt that a preference should be given to thus combining the advantages of the wet and dry ditch: and from what has been said (in paragraph 22) on the general site of fortresses, it is not uncommon to be able to secure these objects: since the flowing and ebbing of the tide on the sea-coast, or its influence on the rivers on which fortifications are so generally constructed, renders such a means of defence available. The batardeaux (definition 35) should be constructed in situations where the enemy's batteries cannot reach them, for if exposed to his fire, these barriers and their sluices would be destroyed, and the ditches made either permanently wet; or, if affected by the tide, the enemy would always know when they were passable. But if the batardeaux and sluices remain uninjured, the besieged may keep the ditches dry as long as the outworks can be defended, and inundate them to increase the difficulty of the enemy's passage across; which may also be swept away, or retarded by well managed currents of water.

133. Ditches have sometimes been made on different levels: the main-ditch being deepest, and those of the outworks shallowest: the objects to be gained by this are as follows: first that, should an enemy get into the ditch of one work, he shall have difficulty in communicating to that of another: for instance, in Vauban's first system fig. 14: if an enemy succeeded in getting into the ditch of the ravelin, he will have a scarp revêtement of thirty feet high to surmount to get within the work; but if he pass round the extremity of the face and get to the lowest part of the gorge wall, he will have only a height of nineteen feet. Now, if the bottom of the main-ditch be six or seven feet lower than that of the ravelin, this could not be done without delay and difficulty: (the defenders communicate by temporary wooden stairs to be removed at pleasure). Secondly, in passing along the bottom of the main-ditch from

the gorge of the ravelin to the stair-cases in the re-entering places of arms, the defenders traverse the open space where the ditch of the ravelin unites to the main-ditch: if the two ditches be on a level, the enemy's batteries on the crest of the glacis, command this space; but if the main-ditch be six feet deeper than the ditch of the ravelin, this space can be safely passed by keeping close to the retaining wall, even although the enemy possess the crest of the covered-way before the ravelin. To secure these two advantages, there must be at least a difference of level of six feet between the ditches. The application of these principles in the modern system gives the depths of the ditches below the level of the ground, as follows: see fig. 211.

Main-ditch	24 feet
Ditch of the ravelin	18
Ditch of the redoubt of the ravelin	6
Ditch of the redoubt in the re-entering place of arms	8
Ditch of the cavalier	(on the level of the ground).

134. A description of the revêtement walls that support the sides of ditches appears to belong to this part of the subject, but it has been thought right to treat of the masonry separately, in Chapter viii.

CHAPTER VI.

Varieties of tracing in the enceinte. On retrenchments.

135. In examining existing fortresses, it will rarely be found that the works are laid out with the regularity described in the first part of this treatise; because many places have been much improved by the addition of modern works, or the alteration of old works; and in others, old works possessing fair defensive properties have been permitted to remain; or modern

works have been built from time to time by engineers differing in opinion as to the value of certain constructions. It would therefore be as impossible as it would be unprofitable to enter upon the examination of the great variety of tracing and details of construction to be met with in practice, differing from the principles explained in the first of this treatise: many of them being most judicious as suited to localities and circumstances; and others having their origin before Vauban's time: but such as are to be commonly seen in the fortresses of our day in the enceinte, will be considered under the following heads.

1. The fausse braie
2. The double flank.
3. The orillon and retired flank.
4. The chemin des rondes.
5. Cavaliers.

136. *The fausse braie* is a kind of second enceinte; it is represented in profile in fig. 17 and in plan in fig. 16; by which it is seen, that instead of one scarp revêtement, the height *ab* fig. 17, is broken into two parts, with a lower terre-pleine (the fausse-braie) and its parapet: its object is to obtain a double fire from the enceinte: and, supposing a front to be without a covered-way, the fausse-braie would serve to bring a second line of fire both of cannon and musketry upon the country; and it is presumed that this work was invented and brought into use before the introduction of the far more valuable construction of the covered-way, which has completely neutralized the effects of the fausse-braie: for as the terre-pleines of these two works are on the same level and the crests of their parapets in the same plane of defilement, it is clear that the defenders in the fausse-braie cannot see the enemy till he arrives on the crest of the glacis, and that their musketry fire cannot retard, or act upon his distant approaches; and, if artillery be used in the fausse-braie, its horizontal fire (definition 6) cannot come into operation till the enemy is forming his lodgment on the crest of the glacis: therefore, whatever may have been the value of this work in the

early stages of shot proof ramparts and parapets, it is quite inapplicable to a front furnished with, and covered by a glacis: besides which it has the following defects.

137. Firstly. The revêtement (which has hitherto been considered as thirty feet high) is broken into two parts; and since the terre-pleine of the fausse-braie is on the plane of site, the lower scarp revêtement is only twenty-two feet in height and escalade is rendered thereby more easy. Secondly. When the enemy has surmounted this lower revêtement and reached the terre-pleine of the fausse-braie, he has it in his power to circulate round the work to seek for embrasures or small breaches (previously made by his batteries) to enter at several points at the same time. Thirdly. As the enemy's guns (*cccc*) on his lodgment on the crest of the glacis (fig. 16) are higher than the terre-pleine of the fausse-braie by three or four feet, there would be no difficulty in their enfilading the faces and flanks of the bastions with great effect. Fourthly. The defenders in the terre-pleine of the fausse-braie would be greatly disturbed and injured by the enemy's shot striking the upper revêtement and detaching splinters of masonry; and the rubbish also from breaches made in it would choke up the passage of the terre-pleine: this could indeed be obviated by making the upper rampart and parapet with a long exterior slope of earth; but to do this, the whole mass must be thrown some feet inwards all round, which would diminish the interior space of the bastion: and considering that this space is already contracted by the construction in fig. 16, nothing but the obtaining of a decided advantage could justify a still further encroachment on this space. A fausse-braie is not therefore an approved construction under the circumstances hitherto described of a regular front on a horizontal plane having a covered-way and glacis. Vauban seeing its defects, suppressed it altogether upon the faces and flanks, and by detaching it from the curtain, he formed the tenaille in the main-ditch.

The fausse-braie has, however, been recommended in the case of a front exposed to the fire of a neighbouring height, as in that case, although the revêtement would be lower it would be better covered by the counterscarp from the view of the hill. Although the fausse-braie has been represented in fig. 17, as having its terre-pleine on the plane of site, yet in many fortresses (especially in the native forts in India) it is lower than the level of the ground by several feet: a construction that renders it still more objectionable.

138. *The double flank* has two terre-pleines and two parapets, and is armed with two tiers of guns; it is, in fact, the fausse-braie upon the flank of the bastion, its profile is the same (fig. 17); its plan is seen in figs. 14 *cp* and 16 *dd*: and although a strong fire is thus obtained not only for the defence of the ditch, but also to contend with the enemy's counterbattery on the crest of the opposite glacis (paragraph 25), it is considered to be a construction more formidable in appearance than in reality: for besides the objections already urged against the fausse-braie, to which the double flank is also subject, it would so entirely interfere with the principles of the relief of the tenaille (laid down at paragraph 117) that this work would have to be altogether suppressed; or made so low, as no longer to answer its many useful purposes, (paragraphs 62—64). Artillerists likewise object to serving guns in a lower battery so immediately under the muzzles of the upper ones; as ignited wadding, &c., issuing from them, renders the service of the lower battery dangerous.

139. *The orillon and retired flank:* this construction is seen in fig. 14; the curve *de* being the orillon; and *co* the retired flank; before Vauban's time, the flanks were frequently cut up by very large square orillons; but he fixed one third of the original flank as the length for the orillon, and the remaining two thirds for the retired flank. In paragraph 137 it is said that the fausse-braie is easily enfiladed by the enemy, which objection holds good against the double flank; now if the flank *co* fig. 14, be retired as here represented with this projecting tower or orillon *de*, and if the lower flank or tier of guns be constructed in the space between *ec* and *op*, then will they be

greatly protected from an enfilade fire by the mass of the orillon; for it must be remarked that the upper parapet is about fourteen feet higher than the lower one, and follows the winding of the tracing *decop*: it is presumed that it was one of the chief uses of the orillon thus to cover the second and lower flank from enfilade.

140. Again, let it be remembered that the object of the enemy's counterbattery *ab*, fig. 14, is to silence the fire of the flank *dp*: in order that the enemy may cross the ditch *h* unmolested by this flanking fire, and assault the face of the bastion; which he could not do while the battery on the flank swept the ditch by its fire; but, in order to prevent this flanking defence being entirely destroyed, Vauban conceived, that from the position of the orillon, one gun might be placed in embrasure at the extremity of the flank *g*, which could view the whole of the face of the bastion opposite (for the line *ceh* is drawn to the flanked angle of the centre bastion) without being seen from any part of the enemy's counterbattery *ab*; and that the fire of this single gun could be reserved, till the critical moment of the assault, to bear in flank upon the enemy. Vauban was also of opinion that the curved shape of the retired flank would allow of nearly as many guns being placed in embrasure, as in the original straight flank. This construction has been very much followed; but on the whole, the single straight flank is preferred; and the following are the objections brought forward against the orillon and retired flank. Firstly, that as double flanks are not approved of (or the reasons already specified in paragraph 138), the main object for which the orillon was used, namely, to protect the lower flank from enfilade, no longer exists. Secondly, that the gun hid from the view of the enemy's counterbattery at the extremity of the retired flank, is not considered as sufficient to deter an enemy from risking an assault; besides which, vertical fire has been greatly increased since Vauban's time, and this single piece of ordnance would, in all probability, be rendered inefficient by the enemy's shells; besides as Sir John Jones

remarks, "It ought to be received as a general rule, that no flank can be formidable to infantry which does not contain at least three pieces of ordnance; and even to render a flank of three pieces very destructive, it must be in a situation of tedious approach, or in a work which cannot be run into." Thirdly, that this curved retired flank does not actually give space for so powerful a battery as a straight flank; nor is its shape so favourable for the forming of embrasures; while a musketry fire, carelessly made from its extremities, would b e apt to injure the defenders on the adjoining curtain or ravelin. Fourthly, it diminishes the interior space of the bastion.

141. *The chemin des rondes* is a berm,* from eight to ten feet broad; and as Vauban used it in one of his last constructions, the fortress of New Brisac, (or as it is called, in this and other treatises, Vauban's third system), it may be supposed that his great experience led him to adopt it. Fig. 18, *a c*, shows the chemin des rondes in profile. The object of it is to enable the officers on duty at night to go their rounds, (hence its name) to observe, more closely, the ditch and covered-way than could be done from behind a thick parapet: cuts or passages are made, at convenient places, through the parapets, to lead from the terre-pleine of the rampart to the chemin des rondes: besides permitting a more minute examination, and a stricter guard to be kept, this form of construction has also the following advantages: Firstly, it permits the defenders to come out to repel an escalade, with their bayonets, from the most advantageous position: whereas, in the common form, (fig, 13, &c.) they are placed behind thick parapets, over half of which their fixed bayonets cannot reach. Secondly, if a breach be made in the revêtement (*c b*, fig. 18), its fall does not immediately entail that of the parapet above, as in the common construction, and a practicable breach is, therefore, more difficult to form; for suppose the wall that supports the mass of the rampart to be battered down, the rubbish would leave a rough slope *d b* nearly parallel to the exterior slope of the parapet; and the quantity of parapet *d a* that would fall in consequence, would depend upon the height of the revêtement, and the breadth of the chemin des rondes, the broader that the latter is made, the less parapet would fall. Thirdly, as the defensive efforts at the moment of assault should be seconded by throwing live shells, grenades, and combustibles into the ditch, this can be much more effectually done from the edge of the scarp wall, on the chemin des rondes, than from behind thick parapets; for the shell, in rolling over the parapet, receives a direction and impetus that causes it to fall into the ditch in a curve, within which assailants are mounting, and are, therefore, comparatively safe. Fourthly, a thin wall of masonry, as *c s*, fig. 18, four or five feet high, may be built upon the exterior edge of the scarp revêtement, which, by augmenting the height of a revêtement, (already supposed to be thirty feet high), renders escalade almost impossible; this wall may be loop-holed for musketry. It is true that nearly all this small wall can be seen from the enemy's batteries (because it is above the plane of defilement of the crest of the glacis), and can, therefore, be beaten down by their fire long before an assault takes place; but this destruction of the wall is only on the two or three fronts commanded and enveloped by the enemy's attack; the other parts of the fortress, which must be always strictly watched during a siege, are rendered much more secure against an enterprise or escalade, by this additional height of scarp.

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* *A berm* is a level space between the exterior slope of the parapet and the top of the scarp: it is a common construction in field works.

142. The chemin des rondes is nevertheless objected to by most theoretical writers, and is omitted in the constructions usually laid down by them: firstly, because it affords a good space for an escalading or storming party to form upon after overcoming the revêtement, and by it to pass round the exterior slope of the parapet, to enter the work at any part, and thus turn (or get in the rear of) any interior retrenchments intended to cut

off the breach and prolong the defence. Secondly, because the interior space of a work, having a chemin des rondes, is diminished by the parapet being thrown in ten feet all round.

143. With regard to these two objections, it is admitted that the second is quite just; but it can never stand in the way of the many advantages already stated as belonging to this work. The first is a more serious one; but it is presumed, that by means of cuts across the chemin des rondes, and obstacles planted on it, that the enemy might readily be prevented from circulating, at pleasure, round the work to turn the retrenchments.

In confirmation of the views of Vauban, the following extract is taken from Sir John Jones's Sieges in Spain, (vol. i. p. 471).

" For the better defence of thick parapets, the French also adopt an excellent expedient, which is, to make a cut two or three feet wide, parallel to the exterior line of the parapet, at about the same distance from it, with occasional communications to the rear. This cut enables the soldier effectually to use his bayonet, which is of no service to resist an escalade from behind a thick parapet, and also admits of his firing much more directly into the ditch, with less exposure to himself. It is from these cuts that the French throw down, with so much accuracy, the immense quantity of grenades and combustibles with which they always second their defensive efforts. From these advanced cuts they are able to drop them to the very foot of the ladders; whereas, from behind a thick parapet, the impetus the shell receives while rolling over its surface, causes it to form a curve during its descent, within which the assailants are secure. Such a cut likewise affords the means of forming a double line of defence. A few cool brave men are sufficient for the front line, and the main body can remain in reserve, sheltered by the parapet. This disposition of the troops to sustain an assault, cannot but tend to prevent that general cessation of defensive efforts which too frequently occurs, on a few of the assailants forcing in at some unguarded point. At Badajoz, many French soldiers in these cuts, not aware that the body of defenders had deserted the interior of the parapet, continued to fire into the ditch after the allies were in possession of the terre-pleine.*

" All these advantages were gained by the ancient chemins des rondes, with the additional benefit of adding to the height of the escarp, at a small expense, and rendering the breach more difficult to form, by the parapet being retired its whole breadth. As this addition to a front costs little, do the objections urged against it justify its omission in all modern fortresses: particularly when it is considered that Vauban, in his latter days, frequently expressed the greatest regret at having omitted it in places he had fortified on his new system ?"

144. *Cavaliers* do not properly come under the subject of changes in the enceinte; for a cavalier is independent of the body of the place; is constructed within it, and has a command over it. This elevated mass usually follows the shape of the bastion: and as in figs. 210 and 211; which show a plan and sections, of the modern system; there is a cavalier *L* in the centre bastion, its dimensions will be here considered as an example of this species of work.

A cavalier is intended to carry a battery of heavy artillery, either to strengthen the fronts in its vicinity; to contend with any local advantageous position the enemy may occupy within its range; or, to look into any ravines and hollows which the general height of the enceinte does not enable it to do: a cavalier therefore must be always placed in the situation best suited for its intended purpose; and that may be, in rear of the curtain, especially on a front without a ravelin: but on a full front, the bastion offers the best position for the cavalier, as, if it have a proper command, there is nothing to mask its efficient fire upon the country, and in support of the other works.

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* " Indeed in the ardour and excitement of a determined resistance, brave men are frequently so occupied with their own efforts, as to be insensible to any thing passing at the smallest distance. At the assault of the lunette of St. Roque, which was carried by escalade at the gorge, whilst menaced and fired upon in front, the officer with the ladders (Lieutenant Wright) was obliged, in going round to the faces, to strike several of the defenders with the flat part of his sword, to make them aware that the work was carried."

By fig. 211, which gives the profiles of the modern system, the cavalier has a command over the country of thirty-one feet; and over the bastion, of nine feet; here the distance from the crest of the bastion to that of the cavalier is one hundred and two feet; and it is this that determines the elevation of the cavalier (on the principles detailed at the end of paragraph 114) so that the faces of the bastion may not interfere with the full effects of its fire upon the surrounding country: by figs. 210 and 211, it is seen that the faces of the cavalier have a revêted ditch of thirty feet wide, which is turned into a retrenchment (paragraph 146) by the cuts made across the terre-pleine of the rampart, but this is not the case with all cavaliers; they generally terminate by a long exterior slope upon the terre-pleine of the rampart of the bastion, and thereby either give greater space to this terre-pleine, or by being brought nearer to the faces of the bastion, the command of the cavalier may be made less.

As a cavalier occupies so much of the interior space of a bastion, it greatly cramps the movements of the defenders on this important work, and does not admit of room for strong defensive efforts on the assault; for which purpose a large full bastion is preferable to a cavalier; as its terre-pleine can be cut up with retrenchments as thought proper and there is space to meet the assault with a large front of troops. Cavaliers in bastions present their masses to the assailant's batteries in parallel lines to the faces and flanks of the bastions, by which both works can be enfiladed from the same batteries, and a breach made in the cavalier through the opening of that in the bastion. A cavalier, however, greatly protects the neighbouring curtains from enfilade and ricochet, as by its elevation it is a kind of great traverse at their extremities.

Means of increasing the strength of fortresses.

145. Different means have been adopted to increase the strength of regular fronts; by adding extra outworks, and advanced works, which the enemy must seize before he attacks the ravelins and bastions; also by the construction of interior retrenchments and double enceintes: by mines, casemated batteries, inundations, &c.; and each of these has its respective advantages, when suitably applied: for instance, advanced works, (above all detached forts in a state fit to defend themselves) prevent a bombardment by forcing the enemy to begin his works beyond the range of his mortars: they give the besieged the command of a great extent of ground without the place, upon which to manœuvre and fight to advantage; and thus to retard the critical period of opening the breach: and, under favour of such a position, an entire army can find refuge, and establish a fortified camp (paragraph 169). Interior retrenchments, on the contrary, have no influence on distant operations; and merely augment the value of the works, in which they are made, by cutting off or isolating the breach, and enabling the defenders to struggle against an enemy possessing it; mines are formidable means in the hands of both parties: casemated batteries under favourable circumstances are of much importance; and inundations are most useful for defensive purposes when they can be formed. Each of these subjects will be considered as far as the limits of the treatise will permit under the heads of

1. Retrenchments.
2. Extra outworks.
3. Advanced works.
4. Detached works, retrenched camps, and citadels.
5. Casemates.
6. Mines.
7. Inundations and manœuvres of water.

149. Both these, however, cut up much of the valuable interior space, cramp the defensive efforts, and interfere with the active service of the bastion: although those portions of the parapets and ditches of the retrenchments that unite the shoulder angles, should not be finished till near the time of assault, that that there may be as much free use of the bastion as possible.

The cavalier retrenchment has especially the disadvantages just named, of contracting and cutting up the interior space of the bastions, and preventing any thing like repelling the assault by meeting the enemy on a bold and great front.

150. Fig. 21 is the retrenchment *à la gorge:* it gives a more free use of the bastion than the foregoing three modes; and it is easily constructed; the extremities being completed at the very last, and the ditches opened through the scarp revêtements at *e* and *d*, that it may receive a flanking defence from the artillery of the flanks of the adjoining bastions.

151. In fig. 21, it may be seen that an enemy in possession of the covered-way can establish a battery at *f*, which, by firing through the trouée of the tenaille, (or the opening *i* of four toises between the flank and the tenaille), can beat down the revêtement at *k*, near the curtain angle, and form a breach; and if the ditches be dry, he can run a sap along the bottom of them, as *z*, *z*, *z*, to lead a party to the assault of this smaller breach *k*, while the main one, in the face of the bastion, is attacked; and, by this, turn every retrenchment that can be made between the gorge and the flanked angle. Objections have, in consequence, been raised to all the foregoing retrenchments, as being liable to be turned by breaches thus made near the curtain angles; and that nothing offers a security but a front altogether within these points, as on the line *m l*, fig. 21. This would, however, in nearly every case, entail an immense labour; for the tracing of such a front *m r o p s l* would fall within the rampart; and, to raise it to a height sufficient to command the terre-pleine of the rampart, would occupy time and labour that could not be given during a siege. Besides which, the tenaille affords good cover for defensive purposes in the ditch, by issuing through the

postern of the curtain; for removing the rubbish of the small breach *k* by night; for preventing the completion of the sap *zzz*; or for taking an assaulting party in flank; that, to permit such a breach to be stormed on a regular front would argue great want of energy on the part of the defenders. And, in a system with great ravelins, as fig. 210, the faces of which spread to the rear and cover the trouées of the tenaille, such small breaches could scarcely be made; especially in the modern system, where (from all the revêtements being perpendicular in front) the trouée of the tenaille is but two toises wide. The methods, therefore, of retrenching already described are, under all circumstances, the best that have been used, especially the gorge retrenchment in fig. 20.

152. To communicate in these retrenchments, posterns under the parapets, of temporary wood-work, like a gallery of mine, is one method: and another more common method is by narrow cuts through the parapets and slight bridges over the ditches, (as seen at *ttt*, figs. 19, 20, 21), defended by traverses, and covered in front by a little close palisading, to give cover to a few riflemen.

153. Every means should be used to render the retrenchment formidable: if the ditches be unflanked, their sides should meet at an angle at the bottom; or, the bottom should be so narrow as not to admit of a resting place or formation on it (see fig. 154). Chevaux-de-frise, iron crows-feet, harrows, &c. should be fixed in the ditch and on its sides, and, if possible, upon the summit and on the sides of the breach itself. Small mines should be prepared to blow away the rubbish of the breach at the moment of assault, so as to make it difficult and, if possible, impracticable to mount; mines also to blow away the whole mass of the breach on the assailants gaining its summit; and small mines or fougasses to aid in the defence of the retrenchment: there should be an abundant supply of grenades, live shells, and combustibles, to shower into the ditch at the moment of assault. If the bastion be empty or hollow (definition 26),

and retrenched by coupures, the interior slope ought to be scarped, to prevent their being turned. Sir John Jones, in describing the storming of the breach at Badajoz, at page 233, vol. i, says: "The rampart behind it was narrow and retained by a wall fourteen feet in height, the breach was isolated exactly similar to the breach at Ciudad Rodrigo, by a ditch and parapet made across the whole breadth of the rampart perpendicular to the parapet. Consequently, after gaining the summit of the breach, the assailants must, by a fresh effort, force over the ditch and parapet, or jump down a wall fourteen feet high. The ascent of the breach had been covered after dark, on the evening of the assault, by harrows, extending nearly over its whole surface, and a row of *chevaux-de-frise*, formed of extremely well tempered sword blades, had been placed along its summit."

Again, in speaking of the assault of the main breach at St. Sebastian, on the 9th of September, 1813, Sir John Jones observes: "Both officers and men, however, nobly persevered in the attempt to close with their opponents; but it was soon discovered that the rampart along the interior of the breach was retained by a wall from fifteen to twenty-five feet in depth, at the foot of which was arranged every nature of defensive obstacle: that all communication along the rampart or parapet by the flanks of the breach was cut off, and that the only possibility of descending into the town was by means of some portions of the walls of the ruined buildings, which, at a few points, united with the high retaining wall at the back of the breach: Farther, this descent and summit of the breach were closely exposed to a well covered fire of musketry from loop-holes formed in the walls of the ruined buildings at the back of the breach."*

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* The former assault, that of Badajoz, cost the Duke of Wellington's army the heavy loss of fifty-nine officers and seven hundred and forty-four men, killed; two hundred and fifty-eight officers and two thousand six hundred men, wounded; and that of St. Sebastian, five hundred killed, and one thousand five hundred wounded.

154. This last observation leads to the consideration of disposing the houses in the neighbourhood of the attacked bastion, to assist in the defence; which is to be done by barricading the streets leading to the breach, and loop-holing the several stages or stories of the houses for a musketry fire. In some countries, where the houses are of a solid construction, and the inhabitants interested in the defence, some splendid instances of a prolonged resistance are on record: as that of Saragossa in Spain, the defence of which lasted from the 20th of December, 1809, to the 20th of February, 1810, the latter twenty-three days of which, was a war of streets and houses.

155. The works *a b*, fig. 22, are cavaliers to the curtains, having flanks which would greatly assist in defending the interior of the bastion, and seconding the retrenchment à la gorge in this figure: the curtain cavalier could be constructed entirely of earth, but, by revêting it, considerable space may be saved; and as it is so far removed from the faces of the bastions, it would probably require to have a command of twelve or fifteen feet over the enceinte. From its position and elevation, the batteries on it would be difficult to disturb by enfilade or ricochet: and it affords excellent means of constructing casemated cover (paragraph 202), as is seen at *b*, where the size of the apartments are shown by their piers.

156. Retrenchments are not confined to the defence of breaches in the bastion, they are also made in the attacked outworks and covered-way; in the latter, the spaces in the re-entering places of arms, especially when they are large, give favourable positions for the forming of retrenchments: for example, in fig. 23, suppose the defenders have been obliged to retire from the more salient parts of the covered-way; instead of abandoning it altogether or being hurried down the stair-cases at its gorge, it would be of great consequence to have a secure post, such as a good parapet and ditch, *a b c*, into which (under fire of their comrades manning its banquette) the defenders could retire, to rally and endeavour to regain the traverses and

covered-way; or if not strong enough to do so, to maintain themselves here to the annoyance of the enemy's lodgment on the crest of the glacis; and when forced to retire, to do so deliberately and in order. In Cormontaigne's method, and in the modern system, the places of arms are enlarged, to hold large solid redoubts, as *o o*, fig. 210.

157. Ravelins should also be retrenched; but as they are never made full as are bastions, the mode of doing so must differ from that of full bastions. A ravelin may be retrenched in the manner described for empty bastions, (in paragraph 153); for example, in fig. 24, if *c* be the breach, it might be cut off by scarping the interior slope of the rampart, constructing a wall or timber revêtement, to support it perpendicularly, from *d* to *f* and from *f* to *e*, deepening it here, if necessary, at bottom, and strewing its foot with chevaux-de-frise, and every obstacle to hinder a descent; then coupures and parapets *d* and *e* completely isolate the salient part of the ravelin. Every ravelin, however, would be the better of a permanent redoubt within it, as *g h i*, which Vauban rarely omitted; and which, in Cormontaigne's and the modern systems, is carried to its full extent. If nothing better can be had, a common thin loop-holed wall will cover the staircase at the gorge, will enable the defenders to bring a fire of musketry upon the breach, and allow of a deliberate retreat being made: such a wall, two feet thick, being incapable of resisting the fire of cannon, should be always lower than the parapet before it, that it may be screened from the enemy's view.

Ravelins having redoubts can be still further retrenched, as in the modern system, fig. 210; where the salient part of the ravelin is cut off by the coupure *r r*; the gorge *p p* has, in this case, a perpendicular height of fourteen feet; and the coupure is itself greatly covered by the redoubt *o* in the re-entering place of arms.

Strong piles of hard wood, each plank about six inches thick, attached to a good beam and sunk in a trench several feet deep, are sometimes used to form a *stockade*, or timber wall from six to eight feet in height; the planks have rectangular cuts previously made in them, to serve as loop-holes for musketry; (see paragraph 326, article palisades). A stockade of this kind is sometimes made with two faces forming a salient angle, at the gorge of a work, to serve as a retrenchment to cover the staircase and secure an orderly retreat. With a ditch in front, and a half-roof sloping to the rear, to cover the defenders from hand grenades, and splinters of shells, it is called a *tambour;* in such cases there is also a small ditch in rear to receive whatever may fall from the roof.*

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* One evil arising from the present mode of fortifying by a regular succession of connected bastions and curtains, is, that an assailant having established himself in one bastion, can pass along the curtains to the adjoining bastions, or descend at once into the town; and thus the possession of one point gives him the means of securing the whole enceinte. To remedy this evil, as well as to provide retrenchments of a description superior to any of those just described, as hastily constructed during the siege, Vauban, in his latter constructions, seemed to prefer the detaching of the bastions from each other, and the forming of a permanent interior line of retrenchment. It appears, that having to remodel the fortress of Landau, he found it surrounded by a ditch and a good old wall with towers at the angles, at about two hundred or two hundred and forty yards from each other; this became the interior side of the polygon on which he worked, throwing his great bastions or counterguards beyond the ditch to cover the towers; the exterior side of the polygon was thus made about one hundred and eighty toises; the main-ditch, the ravelins, and covered-way were traced and finished as usual.

Vauban improved a little upon this construction at New Brisach, a plan of which is given in fig. 212, where the enceinte or permanent line of retrenchment has the curtain, connecting the tower bastions, broken into a front, having small flanks to aid the flanks of the towers in the defence of the ditch of the enceinte, (the shaded portions of the left front of fig. 212, show the masses of the works, the unshaded portions are the ditches). These constructions at Landau and New Brisach have obtained, in military schools, the terms second and third systems of Vauban, respectively.

CHAPTER VII.

Extra outworks: advanced works: detached works: retrenched camps: citadels.

158. Of the outworks usually added to those of a regular front, it is here proposed to notice counterguards, tenaillons, and demi-tenaillons.

A counterguard or couvre-face, has two faces of a narrow rampart and a ditch, constructed on the counterscarp of either a bastion or a ravelin: fig. 23 shows counterguards before bastions *a* and *b*; and before ravelins *s* and *t*; a section taken on the line *a o r* of fig. 23, is shown in fig. 24; here the counterguard *o* is fifty feet thick, its ditch sixty feet wide; and the work in its rear has a command of observation of three or four feet over it. The counterguard is made 50 feet thick, that there may be just room enough on it for the construction of a shot proof parapet, and the working of guns on its terre-pleine; if the base of the parapet occupies twenty-six feet, there will be a terre-pleine, for the platforms of the guns and their service, of twenty-four feet: and although this space is sufficient for all defensive purposes, yet it is too limited for an enemy to establish himself upon: for example, if he were in possession of the work *o* figs. 23 and 24, he is exposed to the full fire of the faces of the bastion *a*; to shield himself from which, he has to construct a parapet upon the side of the counterscarp, which involves in it the transfer of the original parapet from the scarp to the gorge side of the work; as indicated by the dotted lines *z z z z* fig. 24. The object of a counterguard is to cover the work before which it is placed; so that an enemy must beat it down, and raze it almost to its foundation, ere he can see the main work in its rear sufficiently to breach it.

159. A counterguard before a bastion, as *o* in fig. 23, bastion *a*, has the property of covering the faces of the latter from the views of the enemy's batteries on the opposite crest of the glacis, as from *m k*; and not only so, but the flanks *n* and *l*, of the collateral bastions *b* and *c*, are also shielded from the enemy's counterbatteries *m* and *g*: these results show the importance of counterguards before bastions; and that, to breach the faces of the latter, or to silence the batteries of the flanks that defend these faces, the counterguards must be quite destroyed. These two great advantages are however somewhat neutralized by the effects of the tracing which brings the salient places of arms before the bastions and ravelins in nearly the same circumference of a circle (paragraph 44), by which the enemy arrives at these three points *k x y*, at the same time, and establishes his batteries there; and from that at *x*, he sees through the ditches of the ravelin and can still breach the shoulder angles of the adjoining bastions and turn all the retrenchments between the shoulder and the flanked angle.

Now, in examining the effects of the tracing of the counterguards before the ravelins *s* and *t*, the salient place of arms *i* before the bastion, is thrown into a deep re-entering space; to establish himself on which, an enemy would have great difficulty, as he would be seen, not only in flank but even in reverse, from the salients of the adjoining counterguards; it may then be fairly calculated that the two counterguards before the adjoining ravelins must be silenced before a satisfactory establishment can be made by an enemy on the crest of the covered-way of the bastion between them.

And from the narrowness and position of these counterguards, immediately under the fire of the ravelins, it would be almost impossible to prevent the defenders returning from time to time to man them, unless they were actually possessed as well as silenced; and to possess them to the exclusion of the besieged, it would become necessary to capture the ravelins that so closely defend them: therefore, in most cases, to be able to establish breaching and counterbatteries against the enceinte, two counterguards and the two ravelins must be subdued, which greatly augments the defensive properties of fronts having counterguards before ravelins. Fig. 23 also shows that an enemy, at *f* and *g*, on the salients before the counterguards of the ravelin, cannot breach the faces of the bastion *c* between them, near the shoulder angle; but, at *e* and *h*, more than halfway up the face, so that all the retrenchments made in the upper part of the bastion are secure from being turned till the fall of the ravelins.

161. The conclusion to be drawn from the three foregoing paragraphs is, that fronts having counterguards before bastions, and others having counterguards before ravelins, have respectively good properties; although the latter construction gives greater defensive advantages, from the tracing producing great salient and deep re-entering angles in the general outline of the covered-way.

162. The effects of counterguards before both bastions and ravelins is seen in fig. 23, bastion *a* and ravelin *s*, where the enceinte is entirely hidden from the enemy's establishment upon the covered-way; from which he can only breach the outworks, as at *d* and *p*. Counterguards have, in some cases, been continued in connexion, before both ravelins and bastions, so as to form a complete envelope to the enceinte and ravelins; but such a construction, without their re-entering angles being broken by curtains or flanks, would give dead angles that could only be defended by casemated batteries (paragraph 193).

163. The thickness of fifty feet for counterguards has been objected to by modern engineers, as insufficient to stand before the increased powers of artillery; for after the scarp revêtement of such a work is beaten down, the assailant, by throwing shells filled with powder into the mass behind the breach, where they explode and act as small mines, soon blows away an opening (in so narrow a rampart) of a size sufficient to permit his batteries to see the work covered by the counterguard. In the modern system, the ravelin (which is nothing but a counterguard before

a small ravelin) is between sixty or seventy feet thick (see fig. 210), that it may stand against a weighty fire of shot and shell.

Counterguards, being revêted all round, are an expensive construction; and it is, therefore, a matter for consideration whether they give defensive advantages corresponding thereto.

In permanently wet ditches, they can be made entirely of earth, which is the case in Coëhorn's constructions; where they give cover to masonry revêted works in their rear. Counterguards admit of being easily retrenched by coupures, as seen in fig. 210; where the ravelin may be considered as a counterguard, and *r r* the retrenchment or coupure (paragraph 157).

164. *Tenaillons* and *double tenaillons* are works thrown out from the faces of small ravelins, to which they are submitted by a command of three or four feet; fig. 25 shows their construction; *c* and *d* being tenaillons; *f* and *g* demi-tenaillons; the short faces of the former are on the prolongation of the faces of the ravelin: and of the latter, perpendicular, either from the middle of the face as at *f*; or, at one third from the flanked angle at *g*.* By these arrangements all the ditches are defended by flanking fire.

In the early periods of the present system, the ravelins were made very small, and to improve fronts so constructed, they were often loaded with additional works; of which, these in question were, at one time, greatly used in the Flemish and Dutch fortresses. By their position they admit of a strong fire being made from their faces upon the surrounding country, and when constructed on two or more fronts, they throw the salients before the bastions into re-entering spaces (paragraph 44), and therefore hinder the early establishment of the breaching and counterbatteries against the enceinte. But modern engineers do not approve of these works, as it is not considered that they prolong the defence against a powerful and scientific attack; for then the enemy's batteries upon the crest of the glacis, as at *k*, *i*, *h*, command the ditches both of the ravelins and tenaillons, and through them a heavy fire could open nearly the whole of the faces of the adjoining bastions; whereas, with a common ravelin, as fig. 19, the battery *a b* can only make one breach at the shoulder angle of the bastion, as *k*; besides which, there is nothing to prevent the ravelins, as well as their tenaillons and demi-tenaillons, being breached and assaulted at the same time. In short, the defensive properties of those works are not considered as giving a return at all equal to their great expense; and they are thought to be far inferior to counterguards.

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* Demi-tenaillons, as *f* and *g*, are sometimes called lunettes: but, as the advanced works in fig. 30 are called lunettes also, it is advisable to adhere to the term demi-tenaillons, in order to avoid confusion.

165. *Horn and crown works* are thrown out beyond the glacis: those having one front as *e f* fig. 28, are horn works; and those with two fronts, as *a b*, *a c*, are crown works: the former is here placed before a bastion *n*; and the latter before a ravelin *o*: their long branches or wings are in every case directed so as to be flanked by the fire of some of the main works. When three fronts are thus thrown out, they would be called a double crown work; and four fronts, a triple crown work, &c.

These works are intended, first, to occupy a plateau in advance of the place, to include which in the original enceinte would have extended it to an inconvenient and imprudent degree. Secondly, to occupy a tongue of land between inundations; or such obstacles on the flanks, as prevent the work from being turned. Thirdly, to bar a defile between scarped inaccessible height. Fourthly, to cover the head of a bridge, which is commanded from the other side of the river: or in any other situation, where a ridge of hill, or piece of ground, can be occupied by one or more fronts, with obstacles on the flanks to make it impossible or difficult to turn them.

The relief and command of horn and crown works must depend upon the nature of the position that they occupy; and the particular object for which they are constructed: but when circumstances admit of it, they should always be submitted to the command of the main works in the rear.

Those in fig. 28, are merely to illustrate the subject; they should be rarely constructed on a plain, unless it be to cover weak salients, or to obtain some manifest advantage: the suitable situations for them have been already specified, so that these figures serve only to show their general dimensions and arrangement. Their wings should not exceed in length the range of musketry, that is *d c*, *m b*, *s e*, *p f* should not be more than one hundred and twenty or one hundred and thirty toises in length. In classing fronts into great, mean, and small, (paragraph 24) it was stated that horn and crown works have usually exterior sides of the latter class, that is about one hundred and twenty toises of front: and this is the case in the crown work before the ravelin *o*, fig. 28; *a c*, *a b* being each one hundred and twenty toises. Now where the ground is so restricted as to force the front or fronts to be thus contracted, it is unavoidable, and it is proper to make them so; especially when on a plain, because the natural consequence of small fronts is to produce low ramparts, (paragraph 24 and 28) which thus fall under the command of the proper bold relief of the main work in their rear. But if a horn or crown work should occupy a position lower than the works in the rear; or cover a bridge head; it ought to have a full mean front of one hundred and eighty toises, that it may give the usual formidable relief, and present as perfect an obstacle as possible for an enemy to overcome: and this is the case with the horn work before the bastion *n* fig. 28.

The crown work fig. 28, is an attached crown work, because the ditches of the long branches *cd*, *bm* are cut through the glacis and covered-way of the place; this is done that they may be fully flanked by the fire of the faces of the bastions that command them: but this construction is properly objected to, as affording the enemy the means of breaching the faces of the bastions at *d* and *m* from his batteries *t t* at the crest of the glacis of the crown work; and in a dry ditch, of proceeding by the sap *z*, *z*, *z*, to the breach *m*. This is rectified in the horn work *ef*;

on the right branch of which, the glacis is continued in its slope from *r* to the required depth of the ditch of the branch; so that from *r* to *f* it is one continued slope or ramp, swept by the musketry fire of the crest of the glacis *r* and the battery *p* on the face of the ravelin. The left branch of the horn work has its ditch from *e* to *i* of an equal and a proper depth, and it is flanked by a casemated battery at *i*, (paragraph 193), having a postern leading to it from the counterscarp of the ditch of the ravelin *s*. Thus the enemy established on the crest of the glacis of the horn work cannot see any part of the revêtements of main works, and has therefore to work up to the crest of the inner covered-way ere he can form his breaching and counter-batteries. But this construction of the ditches of the branches of the horn work makes it possible for an active enemy to turn the work by the gorge; as the covered-ways, of the main works and horn works, communicate all round, and a rush could be made from *r* into the rear of the horn work; to prevent which, a loop-holed wall of masonry *lk* is built across the gorge, high enough to defeat any sudden attack, and so thin, that, when the horn work falls, the wall is easily beaten down by the artillery of the place, or by small mines previously prepared for that purpose.

These works have been greatly and injudiciously multiplied in many fortresses: in fact, there are few fortified places without them; and the experience of many sieges has proved their inefficiency to prolong the defence, except in cases where localities favour them. Modern engineers generally prefer occupying advanced ground by independent redoubts, that, while they mutually flank each other, oblige an enemy to attack each separately: a construction that will be immediately explained under the head of advanced lunettes.

Advanced works, however, ought always to prove an obstacle to an enemy's progress, by forcing him to begin his attack further from the main works than he would otherwise do; and thus cause him to expend more time and labour than in an attack of similar fronts without such advanced works. As one proof of this, Sir John Jones, at page 13, vol. i. of his Sieges (see fig. 29) in speaking of the attack of Badajoz, says, "Various methods of attack were considered, but all of them required more than the allotted time. Many of the most capable officers and Lord Wellington himself wished the attack to be directed against one of the south fronts; nor can it be denied that, with time, and adequate means in men, stores, and artillery, such should have been the attack; but to approach either of the south fronts (from *b* to *e*), it is indispensably necessary to reduce the Pardaleras detached outwork (*L*), *which would oblige the opening of the trenches at a greater distance than the usual routine,* and would consequently require more labour and time to perform than the attack of a similar front without detached works." At page 11, "The Pardaleras crown work (*L*) is stated to have its escarps low, its ditches narrow, and its rear badly closed."

166. *Advanced ditch, covered-way, and lunettes.* Some writers on fortification state that when the ditches do not yield a sufficient quantity of soil for the construction of the masses of the ramparts and parapets, that an advanced ditch may be made beyond the foot of the glacis, to supply the deficiency, and, at the same time, to prove an obstacle to the assailant; such a ditch is seen in plan, fig. 30, E, and in profile in fig. 31, E; it is made in this shape, without an escarp, that it may receive a defence from the works behind it: but should it be wet, there may be an escarp as shown by the dotted lines below E, fig. 31, provided that the surface of the water be exposed to the fire of the main works: but as such an obstacle, especially if filled with water, would greatly interfere with the free service of sorties, it has been recommended to furnish it with an advanced covered-way and glacis as *F*, figs. 30 and 32; now this advanced glacis must of necessity be submitted to the command of the main or first glacis, else it will greatly mask the fire of all the main works and afford a favourable emplacement for the batteries of the assailant when he obtains possession of it: and, if to prevent this, the crest of

this advanced glacis be made only five feet above the plane of site (which will still, on a level country, mask the fire of the main works) then its terre-pleine must be sunk below the plane of site (as seen at *F*, fig. 32) and, in proportion as this is the case, the covered-way becomes an easy prey to the full effects of the enemy's enfilade and ricochet batteries. As a defensive work, therefore, it affords no advantage to compensate for its disadvantages; but, under the circumstances of ground favouring such a construction, it is very proper to form an advanced covered-way: for example, if a rivulet flows at the foot of the glacis, and the opposite bank affords a position under the fire of the main works, it would be favourable to this construction.*

On a plain, an advanced ditch and covered-way requires to be supported by lunettes, as *A*, *D*, *B*, *C*, figs. 30 and 33; and thus to form a second line of works affording each other a mutual defence; their fire acting together upon the surrounding country and receiving a supporting defence from the main works in their rear. When the ground, before some of the fronts, falls gradually, and spreads out into a plateau or terrace ere it falls more rapidly into a valley or plain, as the irregular line *xuuw*, fig. 33, this plateau *uu* would be the situation for a system of advanced lunettes and covered-way, as their relief could be made bold while they are fully under the fire of the main works; but on a plain *yxz*, fig. 33, it is difficult to obtain for the advanced works any thing like a respectable relief, and submit them at the same time to the command of the main works: and advanced works should never, after they fall, afford an enemy a commanding position for his batteries. It would therefore appear that unless favourable localities offer themselves, the construction of advanced works is, in most cases, injudicious; and that the strengthening of outworks and enceinte is then preferable.

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* In fig. 29 (see paragraph 24) the French ran an advanced covered-way beyond the Rivillas, to communicate between the lunettes *R* and *P*; its crest is indicated by the line *oo*; here the ground is favourable for its construction along the slope of the hill, from *P* to *R*; and the double object of securing a communication and obtaining a fire of musketry, was obtained.

But if a favourable position can be obtained for advanced works, and if their communication be secured with the main works, they greatly augment the defence :[*] obliging the enemy to begin his attack as much further than he would otherwise do, as there is space between the main works and the advanced works; perhaps to induce him to attack on some other side, or when at length forced, the whole lies exposed to the fire of the main works, which have then to be attacked in due form.

The usual mode of illustrating the subject is to suppose the whole of the works to be on a plain or level country: a simple advanced ditch, such as *E*, figs. 30 and 31, is crossed by a bridge when wet; or the counterscarp ascended by ramps or staircases when dry: (fig. 31 being a section on the line *q r* of fig. 30); the moment the sorties issue on the bare counterscarp, they are seen and subject to the enemy's fire before they can regain their formation. Fig. 32 is a section on the line *s t* of fig. 30; which shows a covered-way *F* beyond the advanced ditch *E*; from which a musketry fire can be obtained, as well as a protection for sorties to issue regularly, &c.: but its crest, if submitted to that of the first covered-way by two or three feet, will make its terre-pleine lower than the plane of site, as *F*, fig. 32; and thus subject it to the destructive effects of the enemy's enfilade and ricochet fire: to support an advanced ditch and covered-way properly, requires lunettes, as *A*, *D*, *B*, *C*, fig. 30, and *C*, fig. 33: and, that they may have a respectable profile, it is necessary that the main works should have a bold relief. In their construction an opportunity is afforded for creating great salient and deep re-entering angles in the general outline, by throwing out those on the capitals of the ravelins as far as possible; and drawing in those on the capitals of the bastions: for example, the lunettes *D*, *C*, on the capitals of the ravelins are traced on an equilateral triangle *g o g*, the sides of which are one hundred and fifty toises, (the length of the lines of defence) by which a flanking fire is obtained for the ditch of the lunette and its covered-way: the re-entering lunettes *A*, *B* are drawn in, so that their gorges rest a little beyond the foot of the glacis, and their faces are directed to points about ten or twelve toises from the flanked angles of the adjoining ravelins, that, like the salient lunettes, their ditches and covered-way, may be flanked: thus the place of arms *m* before the lunette *B* is thrown into a re-entering space between *n* and *p*, which is favourable to the general defensive properties. As this tracing renders the salient lunettes more acute than the re-entering ones, it is customary to give the former faces and capitals of thirty toises; and the latter faces and capitals of twenty-five toises: the flanks in both being parallel to the capitals, and ten toises each. By this, they have about an equal capacity, that is, each lunette can hold about two hundred men and a few pieces of artillery, so as to render it necessary to proceed against it in form, but when captured, the interior space is too limited and cut up to afford a good emplacement for the enemy's batteries.

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[*] On the investment of Bayonne by the allied army under the orders of the Duke of Wellington in February, 1814, Sir John Jones states that "on reconnoitring the citadel, the garrison were found labouring in the formation of an advanced line of defence, consisting of four redoubts, connected by a covered-way, at four hundred or five hundred yards from the citadel; but which, being still in a very unfinished state, they protected by strong posts in the villages in its front."

On a level plane, the lunettes should be lower than the ravelins by six feet: this will make them nine feet below the crest of the enceinte, (when the latter is twenty-two feet above the plane of site): now, if the advanced glacis has its crest seven feet above the ground line, the lunettes will have a command of six feet over it, which is sufficient, as the crests of the works are only separated by a distance of sixty feet (viz. thirty feet for the width of the ditch and thirty feet for that of the glacis), paragraph 114. While this arrangement submits the advanced line of works to the command of the main works, it masks considerably the fire of the latter, and throws upon the advanced works nearly the whole service of contending with the enemy till they fall. These works have the advantage of being independent of each other, so that, although they give a mutual defence, the fall of one does not ensure that of the others, which can continue the defence: the general defence can be aided by redoubts at the re-entering angles of the counterscarp of the advanced ditch, as seen in fig. 30 between the lunettes *A*, *D*, *B*: the general slope of the glacis is produced till the necessary depth for the advanced ditch is gained below the ground line, when it may be continued on a level; which would be the case with the salient lunettes; and also with the ditches before the faces of the re-entering lunettes: but the glacis behind the gorge of the latter would be terminated rather abruptly, in order to give a proper height to the gorge wall: indeed, in some cases, it becomes necessary to build a loop-holed wall at the gorge of advanced lunettes when there is a possibility of an enemy turning them. The communications consist either of caponnieres, as that leading from the first covered-way to the lunette *B*, fig. 30; or by posterns as *v* leading from the ditch of the ravelin to the lunette *D*; the latter is the most secure and approved construction, although the caponniere, from being less expensive, is the most common; these caponnieres have traverses to prevent their being enfiladed and to assist in defending them: the defect of this passage is, that it is a ready made trench for the assailant after the fall of the lunettes.

A flèche, or arrow, is a parapet beyond the glacis as *Æ*, *Æ*, thrown up for the purpose of giving cover to a musketry fire from a position in advance of the covered-way; either to enfilade some of the enemy's trenches or to command a low feature of ground, a hollow way, &c.: they communicate to the covered-way in their rear by caponnieres.

Advanced works have sometimes been made open, and sometimes closed, at the gorge: on which subject Colonel Sir John Jones has the following excellent remarks at page 469, vol. i. of his Sieges.

"*Considerations on the usual mode of securing the Gorges of Detached Works.*

"Whilst on the subject of storming works, it may be as well to inquire, whether theory more than experience has not led to the practice of making the rear of all detached works in advance of a fortress without a ditch. Such a construction is often of serious ill consequences, as the assailants never fail to attack such a work at the gorge, and generally succeed by it; therefore, if it be not founded on sound principles, it should be rectified.

"The reasons urged against making a ditch round the gorge of detached works are, that it serves as a lodgment for the assailants after carrying the work, and that it is an obstacle to driving them out of it again by a sortie.

"This reasoning certainly holds good when the work is not advanced beyond the glacis, as then it cannot very well be attacked at the gorge, and the enemy ought to be repeatedly driven out of it; besides, its proximity to the place renders the musketry fire upon it so destructive, as to make immediate cover for the assailants indispensably necessary for their safety. Works in such situations cannot be made too accessible at the gorge; but these considerations lose all their weight when applied to a work more advanced from the place than 500 yards, as then the chance of recovering it by a sortie is nearly hopeless, and any engineer of experience would, instead of entering the work, prefer making a lodgment by the flying sap on its flank, as being more readily executed, and of the most use when finished. Any cover created within the work must necessarily be very confined, and the garrison always prepare marks to direct their artillery, and usually keep up a constant fire on a detached work throughout the night after it is carried.

"The line to draw would therefore seem to be,—no ditch around the gorge of works within 300 yards of the place,—in the construction of works from 300 to 500 yards, to be governed by circumstances,—but to all works beyond 500 yards distant from the place, to make a ditch, and create the same obstacles to an assault round the rear as in front of the work."

167. *Detached and inaccessible works.* A small detached work may, by its inaccessible position, be of great value in prolonging the defence of a place; for example, a redoubt, castle, or casemated tower upon an inaccessible rock commanding much ground in every direction; a well covered earthen redoubt in the middle of an inundation; or on an island or a tongue of land difficult of access; or any work so situated in advance of the place, as to be able to take the enemy's attack on the neighbouring fronts in flank or reverse; and force him to expend much time and means in reducing it;* or induce him to abandon every attempt on the place within the range and influence of such a work, and to form his attack on some distant fronts. In order that such a detached work may answer these purposes, localities must so favour it that an enemy will have great difficulty in establishing heavy batteries of artillery to overwhelm and annihilate its defences;† and that it shall be quite out of his power

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* In fig. 29, *S* is the outline of Fort Christoval, that crowns a rocky height about five hundred yards from the fortress of Badajoz, from which it is separated by the river Guadiana. This detached work, although a small irregular weak fort, occupying a square of only three hundred feet, yet supported by the fire of the fortress; situated on a height about one hundred and fifty feet above the river, and surrounded with ground so bare and rocky, as to render the formation of enemy's batteries extremely difficult from want of soil, twice offered a good and successful resistance, when defended by the French, against the allied army under the Duke of Wellington; on the second occasion (29th May, 1811) even twenty-three pieces of artillery were placed in battery against Fort Christoval, when it was partially breached; and two gallant assaults failed on the 6th and 9th of June; on the 10th of June the siege was raised. (Sir John Jones's Sieges, vol. i.) When Badajoz was finally captured, the redoubt *P* was first taken, and the attack carried forward from *P* to the low ground towards the river.

† As an instance of the sweeping and annihilating effect of a concentrated fire of artillery on a small work, the following instance is adduced. In 1810, the French under Marshal Victor invested

to push up to its counterscarp by the usual process of attack. As such works, in general, must be very small, they require to

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Cadiz; he spread his army round the bay, forming lines of contravallation, of no less than twenty-five miles in extent, enclosing a great number of villages, castles, &c.; amongst the rest there was one small fort called Matagorda, (which was first abandoned by the Spaniards, but afterwards seized by their allies, the English); this fort interfered with the French works, and from it they were determined to drive the English; it was situated on a tongue of land, and separated by the harbour from another tongue of land on which Cadiz is built. The works of Cadiz were above four thousand yards distance from it; but there was a powerful battery on the Cadiz tongue, called the Puntales, at one thousand two hundred yards from Matagorda. Col. Napier, in the 3d vol. of his History of the Peninsular War, p. 178, says, "General Stewart's first measure was to recover Matagorda. In the night of the 22d (February, 1810) a detachment, consisting of fifty seamen and marines, and sixty-seven of the 94th regiment, the whole under the command of Capt. Mc. Lean, pushed across the channel during a storm, and taking possession of the dismantled fort, before morning effected a solid lodgment; and although the French cannonaded the work with field artillery all the next day, the garrison, supported by the fire of Puntales, was immoveable." Again, at page 180, "But now Matagorda, which, though frequently cannonaded, had been held *fifty-five days*, impeded the completion of the enemy's works at the Troccadero point. This small fort, of a square form without a ditch, with bomb proofs insufficient for the garrison, and with one angle projecting towards the land, was little calculated for resistance; and as it could only bring seven guns to bear, a Spanish seventy-four and an armed flotilla were moored on the flanks to co-operate in the defence. The French had, however, raised great batteries behind some houses on the Troccadero; and as daylight broke on the 21st of April, a hissing shower of heated shot falling on the seventy-four and in the midst of the flotilla, obliged them to cut their cables and take shelter under the works of Cadiz. Then the fire of *forty-eight guns and mortars, of the largest size*, was concentrated upon the little fort of Matagorda, and the feeble parapet disappeared in a moment before this crushing flight of metal. The naked rampart, and the undaunted hearts of the garrison, remained; but the troops fell fast, the enemy shot quick and close; a staff, bearing a Spanish flag, was broken six times in an hour, and the colours were at last fastened to the angle of the work itself, while the men, especially the sailors, attributed the slaughter to their fighting under a foreign flag. Thirty-six hours have good casemated cover (paragraph 194), that they may not be immediately forced to surrender from bombardment: and, if possible, their revêtements should be covered by a glacis: the tracing should be so arranged that the prolongations of the faces should fall either upon the main works or upon inaccessible ground, to prevent the enemy enfilading them: the guns should command all approaches, while the embrasures are to be somewhat oblique to the ground on which the enemy can establish his batteries, to hinder him from firing directly into them to dismount the guns.

It is quite impossible to fix either dimensions in tracing or relief for detached works; as these must entirely depend on the situation and object of the work. If a good and secure communication can be kept up with the place, it will greatly increase the value of a detached work, as it permits fresh supplies of men and *matériel* to hold the enemy in check and keep him at a distance from the main works.

Detached works, indeed, become of the first importance to places giving cover to the dock yards, great depôts, magazines, hospitals, &c.; for the range of shells from mortars averages from one thousand yards to two miles; and an enemy may greatly injure, if not altogether destroy, magazines and docks from these distances, unless there be good detached works within range of each other to keep him at a distance, (paragraph 169).

168. *Retrenched camps.* It would be of the first importance to an army that has been forced to retire, pursued by superior forces, to find, on its line of retreat, a strong position, in which to compensate for want of numbers; where it could safely rally, reform, and draw upon its magazines for supplies. Vauban's proposed to obtain these advantages by enclosing a space of

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the tempest lasted, and sixty-four men out of one hundred and forty were down, when General Graham, finding a diversion he had projected impracticable, sent boats to carry off the survivors. The bastion was then blown up under the direction of Major Lefebre, an engineer of great promise, and he also fell, the last man whose blood wetted the ruins thus abandoned."

ground, suited for the purpose, under the guns of a fortress, by lines of strong field works capable of containing a camp of twenty thousand or thirty thousand men : within this position an army could rally, draw from its magazines laid up in the fortress, and perhaps be enabled to act offensively: at all events, to leave a corps of from ten thousand, to thirty thousand, men, within this retrenched camp in addition to the garrison, and thus force the victorious party either to form the siege of such a place; to attack the retrenched camp; or to leave a large corps of observation to watch the place; for twenty thousand or thirty thousand men, on the alert to cut off communications, could not, without great danger and imprudence, be left in the rear. Napoleon said "that fortresses are equally useful in offensive as defensive warfare. It is true, that they will not in themselves arrest an army, but they are excellent means of retarding, embarrassing, weakening, and annoying a victorious enemy." And in proportion as the garrison becomes formidable, will the enemy's delay and difficulties be increased. Now, few fortresses are capable of shutting in a garrison of twenty or thirty thousand men, and a place manned with only three thousand, five thousand, or ten thousand men, can sometimes be masked or blockaded by large detachments, when the victorious army is numerous, without much interfering with the general objects of the campaign or the progress of conquest. To oblige an enemy, then, to delay his masses before a fortress is an object of such importance as to invest retrenched camps with considerable consequence.

Vauban first conceived the idea of thus making fortresses of small or medium size answer important ends in the general operations of war: he formed several at the beginning of the eighteenth century, as at Dunkirk, Lille, &c.: the tracing of which depended upon the localities: the canals and other obstacles that traverse the ground in the neighbourhood of these places affording means of strengthening some sides or diminishing the labour of construction: fig. 34 is a diagram of the retrenched camp at Dunkirk: (the fortifications of the place, which were very strong, are in great part omitted): its general outline, *A B*

E C D, forms as much as possible straight lines, in order that the salients, which are most likely to be first attacked, may be reduced to the fewest possible in number: this tracing rests its base *A D* on the fortress: the space *S S* are the sands, open at low water and covered at high: *P P* are batteries to protect the pier head.

The great outworks on the fronts facing *H* and *G*, omitted in the plan, are so strong as to render an attack on these sides very difficult: the shaded parts represent the wet ditches, rivulets, canals; and *E* is a lake having a high dry space of ground in its centre, occupied by a bastioned fort: the situation therefore is most favourable for the construction of a retrenched camp: and, if the salient parts be attacked and captured, the interior, being cut by a canal, affords excellent means of retrenching. The profile of such a work should be bold; the parapets at least nine feet high, and the ditches from twelve to sixteen feet deep; the counterscarp should be raised two or three feet, and a small glacis formed beyond it to cover a portion of the parapet; every precaution usually taken to render field works secure from a coup-de-main should be adopted in these works (paragraph 326).

169. Continued lines of works for retrenched camps have been disapproved of by some modern engineers as confining the offensive operations of the troops within them. General Rogniat in his work entitled "Considerations on the Art of War," in speaking of points of support in the environs of fortresses to favour the manœuvres of an army upon the defensive, and between which it can change front without danger, in order to meet an enemy on whatever side he may present himself, says: "I see no better manner of fulfilling these conditions than that of establishing four little forts around each place, forming a great square, in the centre of which is the fortress:" *(see diagram, fig. 35, F, the fortress: n n n n, the four small forts)* "these forts should be established on the summits of the most advantageous heights, at about two thousand four hundred

or three thousand yards from the works of the place, and about six thousand yards from each other: the space comprised between two forts, would form a field of battle capable of receiving from fifty thousand to one hundred thousand men, and might be looked upon as impregnable; the forts, armed with heavy guns, would perfectly support the wings, and the centre could be strengthened by field works (*as o, o, fig.* 35) constructed at the moment of need. Thus the four forts circumscribing the fortress, would form all around a vast retrenched camp, presenting four fronts or four different fields of battle, so that face could be made against the enemy on whatever side he presented himself. The ordinary guard for this retrenched camp could be reduced to that necessary for the four redoubts, which could not be more than eight hundred men: the fortress itself serving as a depôt for the subsistence and re-organization of the army. It is easy to vary the disposition of such works to the nature and site of the fortress; to adapt it to the ground; and to profit by natural obstacles, &c."

The good defence of Dantzig in 1813 by the French army under General Rapp, shows the advantages arising from the foregoing dispositions: the following is an extract from the interesting relation of this siege by Captain D'Artois. "The mode of exterior defence presented many advantages: it secured great resources in provision, in forage, in materials, in workmen furnished by the suburbs and villages that we occupied. The inhabitants themselves (whose rising we sometimes feared) formed a good opinion of an army that was not hid within the walls of the place, and hence put more confidence in it; or at least were kept more to their duty by the idea that they had of its power. Let us suppose that an enemy endeavours to reduce the siege to a species of blockade, or small partial sieges, the defenders, having the advantage of a knowledge of the ground, can secure all their positions by fortifying only some points. In this manner they keep the enemy at a great distance, and force him to make such an immense developement as must render him weak.

"It is desirable that we should seek more than we ordinarily do, to prevent the establishments of lines of countervallation, (paragraph 248); or at least to oblige the enemy to construct them at a great distance. The more ground that is occupied, the more easy it will be to have some point to beat the enemy in detail, or to revictual the place. Let us hope that the example given at Dantzig will not be sterile, and that it will serve to confirm the excellent principles expressed by Mons. Carnot in his work on the defence of fortresses, where he recommends that the suburbs should be preserved and fortified for defence, in place of being destroyed on the approach of an enemy, which is too often the case.

"Let us remark, that this is not in opposition to the adopted maxim *to raze all that obstructs the view within the range of cannon;* for after having held the suburbs, hamlets, isolated houses, &c. as long as possible, precautions can be taken to destroy such cover as may be favourable to the enemy, when necessary to abandon it: at least, when forced to take these painful steps, all that depends upon us has been done to avoid bringing such disasters on the inhabitants. This is what occurred at Dantzig, when we were obliged to abandon the suburbs of Ohra and Schidlitz, which were preserved whole as long as we could occupy them. By this distant defence we retarded the bombardment.

"It appears clear to us, that in every respect it is right to keep the enemy as long as possible at a distance from the ramparts: to effect which,all sacrifices should be made, in order to increase the *morale* of the garrison and of the inhabitants, resources of all kinds, the facility of sorties, and the valuable retarding of those incalculable evils that necessarily overwhelm a city exposed to the fire of batteries of all kinds."

The following passage is from a note appended to Lieutenant Colonel Dufour's work on fortification:

"When a place is provided with exterior forts that keep the enemy at a distance, and has a brave garrison to defend the approaches to it, no fear need be entertained of the rockets and bombs of the besieger. All the efforts of an engineer should be directed to give to fortresses the exterior means of resistance. In my opinion, a place that has only a simple bastioned enceinte with a continued covered-way, but which is, at the same time, protected by advanced forts, is preferable to a place furnished with ravelins and retrenchments, but reduced to its own resources and without exterior supports. Perhaps the day will come when the ordinary enceinte of a fortress will be considered only as a last redoubt, and, by simplifying it, greater care and means can be expended on the advanced works. This will not be changing modern fortification, but modifying the use of it. Good exterior forts, mutually supporting each other, will alone be charged with the defence; the place itself will only serve the garrison to obtain a capitulation: the garrison alone will sustain the dangers of the siege; the inhabitants will suffer but little."

These observations are worthy of great attention, in consequence of the increased power of artillery since Vauban's time, especially in vertical fire; when in our day, at ordinary sieges, fifty shells are thrown into a place, for one projected in his time; and when, if provided with a sufficient number of mortars, the assailant can now establish himself at from eight hundred to three thousand yards from the place, and, by a continued bombardment, destroy and fire all private and public buildings that are not bomb proof (paragraph 191). Should the place cover a naval depôt, magazines, or a commercial mart, &c, all may now be destroyed without proceeding regularly against the works of the fortification: it, therefore, becomes a matter of the first importance to keep the enemy at such a distance, by well arranged advanced works, as to prevent these evils; as also to enable a strong and zealous garrison to act offensively under every advantage.

The miseries of a bombardment are so great to the defenceless inhabitants of a town, that every possible means should be taken to prevent it; and no means are so efficient as those just mentioned. "After the surrender of Ath, in 1745, in consequence of a furious bombardment from Marshal Saxe, it was urged against the governor on his trial, and admitted by him, that only fourteen of his garrison had been killed. As the slaughter of the inhabitants and the desolation of the place are described by eye witnesses as having been dreadful to behold, some judgment may be formed from this statement of the usually comparative suffering of the soldier and the citizen under a bombardment."—Sir John Jones's Sieges.

170. Many examples might be quoted of the value of retrenched camps; let two suffice.

Frederick the Great formed a retrenched camp under the cannon of the fortress of Schweidnitz with forty thousand men; not in a continued line of parapet as in fig. 34, but more after the manner represented in fig. 35: by lunettes at intervals; the angles of the general tracé being defended by redoubts, so that he could freely manœuvre and take the offensive when necessary: within these lines, which were constructed in four or five days, he defied his allied enemies, the Austrians and Russians, triple his number.

When the Duke of Wellington's army invaded France by crossing the Pyrenees in 1814, he was opposed by Soult, the most able of Napoleon's marshals; who, on two occasions, endeavoured to make a stand before his victorious antagonists in retrenched camps; firstly at Bayonne and secondly at Toulouse. Sir John Jones speaks of the former in the second volume of his Sieges, as follows.

"Soult had caused his troops to labour incessantly throughout the winter, in strengthening and adding to the capacity of this frontier bulwark; and had formed an advanced line or entrenched camp nearly parallel to the ramparts at five hundred or six hundred yards in their front. This advanced line of works being well supported by inundations and other natural obstacles was of great strength, and covered sufficient space to enable the garrison to form unseen, and unexpectedly to attack with their whole force the works of the besieger, necessarily divided by the Nive; and may be considered to have given Bayonne on the left of the Adour, the strength of a first rate fortress."

Sir John Jones, in his war in Spain, states, that Marshal Soult had an army of thirty-five thousand in 1814, which he ably retrenched around Toulouse: he says, "This city presented many peculiar and great local advantages in furtherance of his labour, being surrounded by a defensible wall, three fourths of which are covered by the canal Royal du Midi, or by the Garonne, an impassable obstacle. Therefore to give that considerable portion of the circumference the strength of a moderate fortress, it was only necessary securely to cover the communications over the canal; and, being zealously aided by the labour of the inhabitants, he quickly effected this by fortifying various buildings and constructing field works of a stronger profile than usual. All direct approach to the remaining fourth of the enceinte not covered by the rivers, was interdicted by the state of the cross roads, being also flanked by a range of bold hills, the summit of which the French had strongly occupied by five redoubts, and had formed various lines of entrenchment in support of them and to connect the flanks of the ground with the defences of the town. At the foot of the heights runs the river Ers, all the bridges over which out of the fire of the works were destroyed. Such was the advantageous position in which Soult decided to try the fate of arms. Yet it was carried by the Allied army under the Duke of Wellington on the 10th of April 1814. But as the operations of the day consisted entirely in the attack of formidable retrenchments, the loss of the victors was very considerable; probably exceeding that of the vanquished: above 4500 Portuguese and British having been killed and wounded, and more than half that number of Spaniards."—See Jones's War in Spain, page 382, plate 4.

In the general arrangements for the defence of a frontier, positions should be selected where, on an extended scale, the militia and ordinary national troops shall possess every advantage; where barracks are built, magazines formed, covered by strong temporary works, in order to avoid the expense of regular fortification; and for this purpose, there is no better plan than that of an entrenched camp, or a system of strong exterior forts.

171. *Citadels.* Definition 32 states the nature and use of citadels. If, in fig. 34, the outline *A B E C D* be considered as the fortress, *K* would be a good position for the citadel, especially if strengthened by natural or artificial obstacles, and works, towards *G* and *H*; in order to render every attempt on those sides so difficult as to induce an enemy to prefer forming his attack against the works of the place. In this position the citadel can communicate with the country, as well as with the sea; so as to be able to receive succour even when the fortress is in a state of siege; while its fronts *A D* command the interior space as far as *B E C*, and thus afford the means of further resistance after the fall of the fortress; or of negociating with advantage for good terms of capitulation: and, in this peculiar locality, it gives an opportunity of withdrawing a great part of the garrison by sea.

It is customary to have a clear space equal in extent to short musket shot range, called the *esplanade*, between the citadel and the buildings of the town; for example, in fig. 34, the supposed citadel *K* would have an esplanade before its fronts *A D*; that, after the fall of the place, an enemy might not be able to lodge himself nearer than this to the glacis of the citadel; for if the buildings of the town were allowed to be constructed close up to the citadel, an enemy could at once establish himself in them, and thus obtain a great advantage.

The fronts of a citadel presented to the country should always be so strong from nature, or art, as to render their defence more lengthened than an attack on the works of the place, and, after their fall, on the inward fronts of the citadel: else the citadel would be attacked, and, when captured, the place would be at its mercy.

A citadel should, if possible, be able to keep up a communication with the country, that succours may be thrown in through it: hence, such a strong hold should have some of its fronts in the general outline of the place, as in fig. 34; for if entirely enclosed within the place, as the castle or citadel of Badajoz, (*h* fig. 29) it loses, in a great measure, this advantage.

Citadels have been objected to, on the score of placing in the hands of a despotic government the means of holding the population in subjection; and that, if an enemy gets possession of them, he has at once the power to overawe the people. These are points which do not lie within the province of military engineers to discuss: to prolong the defence of a place is their chief object. History affords melancholy proof of the sufferings of the inhabitants of fortified cities during a siege and bombardment, and of their natural endeavours to abridge their duration by inducing the governor to surrender; when, perhaps, the safety of a state or kingdom depends on detaining a victorious enemy before the gates of the place. Under such circumstances, it is likely that no power less than the last resource of pointing the batteries of the citadel upon the place, to overawe the discontented, would enable a garrison to persevere in their duty to their country; for although the feelings and exertions of the inhabitants may, at first, be favourable to the defence, their sufferings and terrors soon turn the scale: hence the great advantage of the good detached works and the exterior system of defence spoken of in paragraph 169.

In conclusion, the words of Napoleon are quoted: "If circumstances prevent a sufficient garrison being left to defend a fortified town, which contains an hospital and magazines, at least every means should be employed to secure the *citadel* against a coup-de-main."

CHAPTER VIII.

Revêtements; bomb proofs; casemates.

172. In order that the masonry work necessary for the construction of revêtements, casemates, and countermines in a well ordered fortress, may come under one head, it is proposed to follow these three subjects in the order laid down; for although their defensive objects and uses are unconnected, yet a consideration of the first will throw a light upon the quantity of masonry necessary to be expended on the others, in order to give them proper stability without waste of this valuable material.

On revêtements.

173. The sides of the ditches, and the extremities and gorges of the works, are usually supported by walls of masonry, the construction of which being the most expensive part of a fortress, various means leading to economy in their erection has been proposed, consistent with the preservation of the defensive properties of the works.

174. It is true that, in some cases, the exterior of the rampart has been laid out in a great exterior slope of earth without any revêtement, as in fig. 38; but such a slope must have a considerable base to enable it to stand firmly, without injury from the action of the weather or time. In earth of common tenacity, a base somewhat greater than the height should be allowed for so great a slope; hence, if the vertical height from the bottom of the ditch to the foot of the superior slope be thirty feet, the base should be about forty feet, fig. 38. In earth of a loose character, this base would necessarily become so extended as to occupy an inconvenient space of ground.

Such an arrangement, however, has been recommended in some systems: the famous Dutch engineer, Coëhorn, constructed his counterguards of this profile to cover the revêted works in their rear: but it must be remarked that his ditches were wet: and such a construction is totally inapplicable to the present system of fortification, unless the ditches be so: even then, such a long sloping exterior bank, worn away by time and weather, intersected by wild plants, and cut up by the enfilading and other fire from the distant batteries of attack, will offer great assistance to the besieger when he comes to effect the passage of the ditch: and it is not an approved construction on fronts liable to be attacked.

In a system recommended by Mons. Carnot, minister of war under Napoleon, he proposed the same profile, but his tracing differs greatly from that of the bastion system; and he detaches his revêtement wall from the rampart, and places it alone in his dry ditch, (fig. 38 *d*): this, as well as the other defects of his system, have been ably exposed by General Sir Howard Douglas, Bart., in his work on Carnot's system; and by Colonel Sir John T. Jones, Bart., in his second volume of Sieges.

175. In order to economize masonry, ramparts have been often partially revêted; having long exterior slopes terminating in a berm, fig. 39; but such a construction is only suited for wet ditches, since the height of the wall can rarely offer a serious obstacle to escalade: and, once on the berm, the assailants pass round this road at their pleasure, to seek for embrasures or other facilities of entrance.

176. The mode of revêting most generally followed and most approved of, is to build up the masonry to the foot of the exterior slope of the parapet, so as to be in the same horizontal plane as the crest of the glacis. This is called the *full revêtement*, fig. 40; but Vauban, in some cases, even supported the exterior slope of the parapet by a small wall of masonry, thus augmenting the height of the wall by several feet, and rendering escalade almost impracticable. This is the *entire revêtement*, fig. 41, and

in the third system of Vauban, which represents the fortress of New Brisach (one of his last constructions), we find that he adopted the entire revêtement in the redoubts of the ravelins and in the enceinte: both of which works may be considered as strong retrenchments to the ravelins and great bastions, (see fig. 212); and consequently not so exposed to have the parapet wall destroyed by a distant, or even by a near, fire, as the ravelins and great bastions, which lie exposed to the enemy's batteries on the covered-way. Entire revêtements, therefore, unless fully covered by works before them, must necessarily rise above the crest of the glacis, and are unfit for the generality of works since they can then be beaten down from a distance.

177. The sloping full revêtement, then, being the most common construction, an explanation of it, and of the counterforts usually attached to it, is now proposed.

178. All scarp revêtements should be high enough to render escalade difficult; that is, they should never be less than thirty feet:* Vauban considered thirty-five feet as a height sufficient to render escalade impracticable, with any thing like a resistance.

179. Counterscarp and gorge revêtements should have a height sufficient to render any attempt to jump into the ditch impossible or very dangerous; that is, such walls should never be less than ten or twelve feet in height.

180. From what has already been said of the proper breadth and depth of ditches, (paragraph 126) and of the necessity of their being fully flanked, it appears that an attempt to obtain scarp revêtements of much more than thirty-five feet in height, would involve in it either a great and defective change in the tracing to secure a flanking defence; or, by adhering to the

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* The revêtement escaladed by the assaulting party of the Duke of Wellington's army at Badajoz, on the 6th April, 1812, varied from twenty-eight, to thirty-one feet and a half, high; and of the castle wall at the same place, from eighteen to twenty-four feet.—*Sir John Jones's Sieges, vol. 1. page 287.*

received tracing, it would become necessary to sacrifice one of the most important principles of permanent fortification, namely, a fully flanked ditch. This is a proof, in addition to many already mentioned, that by pushing any advantage too far, a disadvantage immediately arises elsewhere. This refers to revêtements under ordinary circumstances: ditches from forty or sixty feet deep exist in some fortresses; but their tracing and localities do not fall within the rules of the regular works here treated of.

181. Having shown what should be the general height of revêtements, it remains to consider what should be their thickness and strength.

The pressure on the back of a revêtement wall is usually represented by a triangular portion of earth, *c a b* fig. 42: for, in earth of common tenacity, a bank will wear away from the action of time and weather, into a slope having a base *c d* equal to its height *d b*; hence as the tendency of the mass of earth in rear of the revêtement is to seek this slope *b c*, the pressure may fairly be represented by the mass *c a b*.

By enquiring into the nature of the resistance that revêtements offer to this pressure, it is soon seen that the building of a plain rectangular wall is not the best mode of expending the masonry so as to offer the greatest resistance to the pressing mass.

For example, let figures 42 and 43 represent the sections of two revêtements containing a like quantity of masonry, and each thirty feet in height; so that the amount of the pressure is the same in both cases. Let *x* be the centre of gravity in both revêtements; the perpendiculars *x g* cutting the bases *e c* and *i h* in *g* respectively: then in the rectangular wall, fig. 43, the base is divided into two parts at *g*; but in the common sloping wall of fig. 42, *e g* is more than half the base *e c*. Now the pressure exerted to overturn the wall on the pivot *e* in fig. 42, is resisted by a force equal to the quantity of masonry (*l a c e*) multiplied into the lever *e g*: but in fig. 43, the resisting force is equal to the same quantity of masonry multiplied by ig: therefore the resisting power in fig. 42, is to the resisting power in fig. 43, as eg to half ih. Hence, of two revêtements with a like quantity of masonry, that built with a slope in front, of the common profile, is stronger than a rectangular one.

182. The slope usually given is one-fifth or one-sixth of the total height of the wall; that is in fig. 42, lm or oe is equal to one-fifth of the perpendicular height me.

183. Vauban generally gave his revêtements a slope of one-fifth: whatever might be the height of the wall, he made it five feet thick at top, so that the thickness at bottom would entirely depend upon its height; consequently his high revêtements appear to have a weak profile, and his low ones look too massive; and this certainly would be the case with counterscarp revêtements, where the pressure is always represented by the triangular portion in the rear, which demand for high revêtements a greater thickness at top than for low ones.

184. But in a low scarp revêtement, Vauban's rule cannot be far from the truth, since the pressure is increased beyond that bearing on a revêtement of common height; in consequence of the mass of the ramparts and parapets above, being generally so much greater, when masonry has been economised by a partial revêtement: that is, when the relief of the partially revêted, and the full revêted work, is the same, as in figs. 40 and 44; for in addition to the triangular space sqr in fig. 44, there is a still greater mass $prut$ exerting its thrust against the revêtement; whereas, the mass P fig. 40, is less than the triangular portion cab.

It is to be observed that in works having demi-revêtements, this pressure is usually lessened by the construction of a berm: but, as in fig. 44, the line qr is equal to fifteen feet, no berm of a less breadth than this would serve to remove altogether this additional pressure: and such a breadth of berm is rarely or ever made.

185. All revêtements have the masonry secured from the penetration of rain, by a flat stone on top, known as the coping stone or cordon.

186. Instead of laying out all the masonry in the construction of the revêtement wall, a considerable portion is applied to the building of buttresses or counterforts in rear of the revêtements: these are fifteen or eighteen feet apart, as in fig. 45, (which is a ground plan of the masonry).

This arrangement is preferable to that of expending all the masonry in a plain wall; for, it not only gives a greater general base to the mass, and thereby resists better the pressure upon it: but these projecting counterforts greatly break the continuity of the general pressure; for the earth immediately around them, as *aaa* fig. 45, pressing and grasping them, relieves the wall greatly. In a military point of view, counterforts are very valuable, as it has been found more difficult to batter down a wall thus supported, than a plain revêtement without counterforts: for after the revêtement is beaten down, the settled earth is kept hanging together by the counterforts.

Counterforts are either rectangular as *R*, or diminished as *D*, fig. 45. Vauban used the latter: and their dimensions depended on the height of the revêtement: to a revêtement ten feet high, he gave counterforts four feet long, and three feet wide at the root or thickest part; the breadth at the tail, or thinnest part, he always made equal to two-thirds of the thickness at the root. For every additional five feet of height added to the revêtement, he increased the dimensions of the counterforts, by one foot in length, and half a foot in thickness at the root.

187. In order to render revêtement walls as stable as possible, they should rest upon, and be connected with, good foundations; as instances have been known of the revêtement having been pushed forward and separated from the foundation, in consequence of the masonry being bad.

The breadth of the foundation should, in all cases, exceed that of the revêtement: in the profiles, from fig. 39 to fig. 44, the offset, for the foundation is only to the front, and this suffices in revêtement walls, where the pressure is all from the rear: although a double offset is necessary in the common walls of edifices to ensure stability.

The dimensions of foundations depend upon the nature of the soil on which the walls rest: and, when the general situation of fortresses is considered, covering as they do, naval depôts, dock yards, arsenals, or commercial marts, on rivers, &c., where there must be much unequal, soft, and deceitful soil, it becomes necessary to lay the revêtements on good foundations fully capable of bearing the weight of masonry, equally, and without giving in any part: to effect which, they often require to be piled: that is, strong beams of wood, pointed with iron, are driven into the soft ground, by means of a heavy weight (called the monkey or ram) raised up by an engine to a height of about thirty feet, when it is suddenly released, and falls on the head of the beam with its full gravity: which process is continued till the pile is so firmly fixed, as to resist further impression from the ram, and consequently is more than sufficient to bear the weight of masonry which it has to sustain: the head of the pile is hooped with iron to prevent its splitting.

It has been ascertained that, for the quantity of masonry contained in military revêtements in general, the piles need not be so great as in the construction of piers for bridges; piles of about one foot in diameter will suffice: they are driven in about three feet from each other, in the length and breadth of the space intended for the foundation: they are then sawed off at the same level, and connected by horizontal beams crossing each other; so that a strong grating is formed to receive a platform of wood, upon which the masonry foundation of the wall is laid. It is usual, also, to clear away the loose soft soil for about two feet below the heads of the piles, and to fill up the space with rough dry masonry rubbish, as a further security for steadying the piles and keeping the foundation dry; see fig. 46.

Thus a sufficient strength is obtained to bear the whole weight of the masonry and prevent it from sinking; but as the nature of the pressure on the back of rampart revêtements, is to thurst them forward, it will tend to prevent this, if a line of sheeting piles be driven in just outside of the revêtement, their heads being sawed off on a level a little above the bottom of the masonry; as seen in figs. 46 and 47.

When it is thought necessary to lay the foundation with great care and strength, for such works as the piers of bridges, dock yard walls, &c., the space to be built upon is enclosed by a dam to exclude the water; these dams, called cofferdams, are made by driving down two continued lines of piles, at a certain distance from, and parallel to each other: this space between the parallel lines of piles, being first quite cleared, is afterwards filled up with regular brick work and becomes the wall of the cofferdam: the interior ground is then cleared by pumping out the water and laying it perfectly bare, and a sound foundation is sought either by excavating till a firm soil is found, or by piles. Fig. 47, is a section of one of the piers of the Southwark iron bridge, the foundation of which was laid by cofferdams. This figure is taken from the mechanics' magazine No. 445, where Mr. Christopher Davy makes the following observations: "The practice of piling for the support of such a cumbrous mass of materials as the bearing piers of a bridge, has been most generally observed, and as generally found to be adequate to the purpose. But of the use and abuse of piling, it will be necessary to speak. The main use of piling being for the purpose of passing from a loose to a denser soil, it is necessary that that soil should be of such a density as to prevent the piles from sinking farther than they are driven in the first instance, by the pile engine. From the enormous load they bear, this is most likely to be the case, should the pointed ends or feet of the piles not rest on ground of great solidity. Indeed it has been observed in my former papers that piling is only a mode of *searching for firm ground* where it is either inconvenient or too expensive to barrow out or excavate the soil. There are, however, some instances (such as a bed of stiff tenacious clay) where it has been found, by experiment, that although the feet of the piles rest upon no other security than on the clay, a pile ten or twenty feet long, driven down, will, by the friction of its sides, have a hold of the ground nearly in proportion to its actual superficies.

"It is evident, therefore, that piling under two or three very different circumstances, may be made subservient to the effectual security of a foundation. The foundations of the bearing piers of Southwark iron bridge were laid in cofferdams. They are of an elliptical form, with a triple row of piles of whole timber. Each pier rests upon a massive timber platform supported by piles. Close to the outer edge of the offset of the pier, a row of timber sheeting-piles was driven, a precaution that at once exhibits the master mind of the late John Rennie. This uniform belt of timber forms, as it were, a close stationary dam, preventing the soft substratum upon which the piles rest, from being pressed outwards by the weight of the pier; a circumstance that generally takes place where piling is employed, and the work heavy."

This pile work of timber, would in India, soon be destroyed by the ravages of the white ant; and for ages edifices have been secured on the sandy soil on the Coromandal coast, by resting the walls on wells which are constructed in the following curious manner, by a *caste* of people called *well-sinkers.*

The ground to be built upon is excavated and cleared away, as far as the loose nature of the soil will permit, where it is levelled and the wells are formed and founded on this surface: the wells are of two kinds, of bricks or of pottery, the former about four feet in diameter in the clear, and the latter three feet.

Colonel de Havilland, of the Madras engineers, gives the following account of these wells as prepared for the foundation of St. Andrew's Church, at Madras. A depth of fourteen feet below the surface being excavated and levelled on which the work was begun.

"The process of sinking these wells is as follows. If of brick, the bricks are made purposely for them, and of a shape to fit each other in their breadth in circular layers, like the voussoirs of an arch, of the usual thickness, and about seven inches long; a little longer as the diameter of the well increases. Before these bricks are laid, a ring of wicker-work, of the diameter of the intended well, and as broad as the bricks are long, is placed on the surface, and on it the bricks are carefully laid in horizontal layers, with a little clay mortar, very liquid, between them. A cylindrical wall is thus raised to a convenient height; or if known, as high above the surface as it may be required to sink the wells below it. The cylinder thus formed is firmly bound together outwardly, with hay or straw ropes or twists, wound round it from the bottom to the top: this done, the well-sinker gets into the cylinder with a basket, and with his hands chiefly when the mud is soft, sometimes with a short-handled-hoe, and other fit tools, he excavates the soil from the bottom and fills the basket, which is then haled up by other workmen on scaffolding above, and handed out of the way. In this operation great care must be taken to excavate evenly all round under the wicker-ring, that the cylinder may preserve its perpendicularity. The process is thus continued, until the cylinder disappears beneath the soil, or until the bottom is found to be of sufficient consistency for the object in view. If the cylinder be not long enough to reach to such a soil, it is raised again and bound round as before, and the well sinker continues his work till the object, a good soil, or rock, is attained. The well is then filled with brick bats, sand, shingle, small stones, or any other substances which will not dissolve or alter in their volume in water, and will admit of being rammed down to a solid consistency.

The wells having been placed as near to each other as practicable, the interstices between them are very limited; but these interstices are also to be filled up and rammed down with the same kind of materials as the wells themselves: the whole space is then levelled to an uniform surface, perfectly firm and impenetrable, on which the masonry of the foundation is established."

The pottery wells are fitted up and sunk like the others, but the cylinders are formed of baked rings, formed in frames, two to three inches thick, and five to six in height, in lieu of bricks. These, however, are seldom used for wells much more than three feet deep; while, on the contrary, wells even from twelve to fifteen feet in diameter, are often sunk with brick in the way described above, and to a very great depth.*

In further detailing the foundation of St. Andrew's Church, Colonel de Havilland says, that "the wells were sunk about nine feet, the foundations being raised about thirteen feet and a quarter above that, and a basement of four feet more, made the whole depth below the pavement about twenty-six feet and a quarter. But even at this depth the soil was still of the nature of *quicksand*, and to appearance not very solid; but it was a *sand*, a substance that would not dissolve or alter its volume. But the whole area being uniformly the same, no apprehension was entertained of the result, as each part would be sustained in equilibrio." And St. Andrew's Church, built in 1818, stands firmly on its bed of wells.

The wells in this edifice, as also those under nearly all the buildings about Madras, and the revêtement walls of Fort St. George, rest upon sand; and their stability affords a proof of the correctness of the opinion expressed by Mr. Davy, in paragraph 187, "That although the feet of the piles rest upon no other security than clay, a pile of ten or twenty feet long, driven down, will, by the friction of its sides, have a hold on the ground nearly in proportion to its actual superficies;" more especially when rendered solid, as in the Indian modes of ramming the spaces between the wells with dry rubbish for so great a depth.

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* Colonel de Havilland also gives a sketch of the habits and labours of the *well-sinkers' caste:* they intermarry amongst themselves only; they travel about in small companies or families in search of employment, except in such a place as Madras, where they find such constant employment as to induce them to build permanent huts: they work hard, receive high wages, and their constant immersion in water induces them to drink spirits, which leads to improvident habits. While sinking the wells, almost in a state of nakedness, they continue at their work, although the water gains upon them, by diving beneath and remaining below a considerable time: baling the water continually would not only be very expensive with their simple contrivances, but by the process of doing so, the water would find its way between the interstices of the bricks, would wash away the mortar, and derange the cylinder, which would then fall in. In pottery wells, however, it must be done, as the sinker is embarrassed for room. The exertion of working is great, so that they relieve each other frequently.

In a treatise of this kind, it is not necessary, nor is it possible, to enlarge upon the subject of securing the foundations of walls: enough has been said to show the importance of the subject, without a consideration of which it is impossible to arrive at any just conclusions on the point proposed for investigation; namely, the proper thickness and strength of revêtement walls.

Referring to paragraph 181, descriptive of the nature of the pressure of the earth on the back of a revêtement, and to paragraphs 186 and 187, showing how this pressure is lessened by the construction of counterforts; and, again, how the whole mass of supporting masonry is bound to the foundation, as has just been stated; it follows, that, in considering this pressure, great allowances should be made for these modifying circumstances.

188. As the mathematical mind and great scientific experience of Vauban are fully acknowledged, it will be well to inquire into the quantity of masonry generally used by him, especially as his revêtements have stood the test of time.

In fig. 40, let the revêtement have a perpendicular height of thirty feet; then, according to Vauban's arrangement, the slope will be one-fifth of the height, or six feet; the thickness of the wall at top five feet, and at bottom eleven feet; the area of the section of the revêtement is $\overline{5+11}\div2\times30$, or 240 square feet of masonry.

To this must be added the proportion of masonry contained in the counterforts; Vauban's diminished counterforts, (for a wall thirty feet high) at eighteen feet apart, were each eight feet long, with a mean width of four feet; therefore, (8×4) 32 is equal to the area of a horizontal section, which, being divided by 18, (the distance of the counterforts from each other), $\frac{32}{18}=1{\cdot}77$ feet, or the mean thickness of masonry, which would be added to the profile of the revêtement, if the whole of the masonry were expended in a plain wall without counterforts: the section, in fig. 40, would therefore have a mean thickness of 1·77 feet to be added to it: which, in a height of 30 feet, (30 × 1·77) gives 53·33 square feet to be added to the 240 already found; giving a total of 293·33, as the average area, in square feet, of masonry, in a section of Vauban's revêtement 30 feet high.

Now, to ascertain the area of the mass of earth pressing on this revêtement, in fig. 40, and represented by the triangular mass cab and the figure P; let $ac = ab$, therefore $30 \times 15 = 450$ feet: and the area of P, according to the dimensions in the figure, proves to be 382·5; making a total of 832·5 square feet.

The quantity of masonry in the section, in square feet, is 293·33, and the earth (on the scarp) pressing on it is 832·5; that is, the quantity of masonry is, to the pressure of the earth, as 35 to 100 nearly.

It is usual, in calculating the strength of Vauban's profiles, to include, in the mass of masonry, the content of the small exterior wall that supports the parapet (fig. 41), which alters the shape of the profile, and, of course, changes the proportions given above; and then, according to Colonel Pasley,* the quantity of the masonry, and the pressure of earth acting upon it, in Vauban's profile of an entire revêtement, 30 feet high, is as 324·856 to 555·125, or as 58·731 to 100 nearly; whereas, the calculation here offered, according to fig. 40, is about 35 to 100.

After minutely investigating and calculating Vauban's profiles, and laying down some satisfactory tables on the subject, Colonel Pasley remarks; "Still, as there is a difference of ratio, at different heights, which, although not very great, may certainly be considered as a defect in Vauban's general profile; it may be deemed best, instead of following implicitly the rules laid down by him in his tables, to adopt from amongst the various ratios, used by him, that which is the least expensive, of all whose strength has been fully proved by experience. Now, it is well known, that Vauban's revêtements were generally about thirty-two feet high, measuring from the level of the ditch to the cordon, that is to say, without including the small exterior revêtement of the parapet. He may occasionally have made his revêtements lower, but seldom or never higher than the above dimension. We may therefore call thirty feet the average height. But by the second table, it appears that at the height of thirty feet, the total quantity of masonry in Vauban's general profile, is to the pressure of the earth, as 58·731 to 100:" which proportion, Colonel Pasley is of opinion, may be safely followed in practice at any height of profile whatever: and that, in no case should the masonry be in a less proportion than 50·312 to 100.

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* See Colonel Pasley's Course of Elementary Fortification, vol. ii. chap. 24.

It appears, therefore, by the calculations founded on the dimensions in fig. 40, that this profile is not sufficiently strong, and to make it so, a quantity of masonry must be added to it so as to bring it to the proportion required of 58·731 to 100.

In counterscarp revêtements, the pressure is evidently not so great as on scarp revêtements. Let fig. 42 represent a counterscarp revêtement; and compare it with the scarp revêtement in fig. 40: in the former, the triangle cab alone represents the pressing mass, the area of which (supposing the height ac to be 30 feet) is 450 square feet; so that the revêtement is relieved from the pressing mass P ($=382·5$) of fig. 40. Let the masonry in fig. 42 be equal in quantity to that in fig. 40, the area of the resisting mass will then be 293·3; the masonry is then, to the pressure, as 293 to 450, or as 65 to 100. Here, then, the profile proves to be unnecessarily strong, and the quantity of masonry must be lessened, to bear the proportion of 58 to 100; under the supposition that this standard of Vauban's is received as a guide when the masonry is good.

189. The nature of the pressure, and the resistance offered to it, as shown in paragraph 181, lead to the conclusion, that a *leaning revêtement*, according to fig. 48, is stronger than either the rectangular (fig. 43) or the common sloping revêtement,

(fig. 42); all containing a like quantity of masonry: for in comparing figs. 48 and 42 together, (supposing each to have the same height and slope), the length of lever, (formed by the perpendicular, from the centre of gravity to the base) is equal in both, while in fig. 48, the pressing space is lessened by the triangular portion *acd*; consequently, such a construction opposes a greater resistance to the pressure; and if thus superior to the common sloping revêtement, it must be so also to the still weaker rectangular profile, in fig. 43. How far the slope of this leaning revêtement may be carried, is a matter still to be decided by practice and investigation.

190. In the common revêtement, with the slope in front, the greater the slope, the more is the wall exposed to the action of the weather, and unless the masonry be kept constantly pointed, the interstices get soaked with rain: mould, vegetation, and the seeds of plants will be generated in them, and the walls become quickly injured and weakened: this has been the cause of the destruction of the revêtement walls of most of the existing fortresses.

To obviate this, the slope in front has been gradually diminished from one-sixth to one-tenth and one-twelth, &c.; till at length it is recommended to have the wall perpendicular in front, and the slope made in rear as in fig. 49, called the *countersloping revêtement*. The back of the wall is built in steps, as seen in the figure to break the continuity of the pressure of the earth against it. Here the lever of resistance *e g* of the mass of the masonry is less than in any of the other profiles: for, with a like quantity of masonry and a like slope to the walls in figs. 42 and 49, the lever of resistance *c g* in the latter will only equal the portion *c g* in the former: hence the wall is a weaker profile than any of the other constructions: besides which, the amount of the pressing mass is actually increased over that in figs. 42 and 43, by the triangular portion *a c d;* and by twice this mass over fig. 48. Although this profile has been approved of by the authors of the modern system, it has now been shewn to be theoretically weaker than any other, even weaker than if the masonry were expended in a rectangular wall.*

Casemates and bomb proofs.

191. One of the first endeavours on the part of the besieger is to silence and dismantle the defences: this he seeks to do from a distance of about six hundred yards from the works of the place, that he may afterwards work over this space in comparative security. The chief means used by him are enfilade, ricochet, and vertical fire, (paragraph 8). To neutralize the effect of the two former, it is usual to construct traverses† between every two or three guns, which, under ordinary circumstances, (on ramparts from ten to fifteen feet above the enfilading batteries), are efficient to screen the guns greatly. Ricochet fire has, (through the works of the French military engineers), obtained a great reputation in the attack, as irresistible in silencing the lines of works subject to its action; but the results of the practice carried on at Woolwich in 1821, by the Royal Artillery, lead to the opinion that well traversed works cannot readily be silenced by enfilade and ricochet fire. The pupil is referred to note 83 in the second vol. of Sir John Jones's Sieges, which is here transcribed, and which shows the true value of this species of firing.

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* The pupil is referred to appendix, No. 1, for full information on the subject of the pressure of earth against revêtement walls; illustrated at Addiscombe by a model.

† An example of this is seen in the four-gun battery in front of the mansion-house at this seminary.

Note 38 : Page 356, Vol. 2. Sir John Jones's Sieges in Spain.

"All the attempts made at this attack to overwhelm the artillery of the place, were by direct fire; and perhaps with some reason, considering the complete success obtained by that means at Ciudad Rodrigo, and the little effect produced by the enfilading batteries, à ricochet, at the reduction of Badajoz.

"This naturally leads to a consideration of the most efficient employment of ordnance to silence ordnance, and to inquire into the real value of the enfilade fire à ricochet, which is generally considered as being applicable to all distances, and to be of itself infallible. This colossal reputation was, in all probability, first acquired by enfilade fire, from being powerfully and judiciously employed, whilst it surprised by its novelty, and before means could be devised to ward off its effects. Ricochet shot then bounded freely along whole lines, dismounting the guns, breaking the platforms, and sweeping away the defenders; but sober judgment and every day experience, lead to much doubt of an enfilade fire à ricochet, possessing any such destructive properties against lines well traversed and defiladed. No shot fired with only a few ounces of powder, can possibly have sufficient force to penetrate through, or knock down, a moderate obstacle; and, consequently, a ricochet shot can injure troops or guns which are well and closely covered by traverses, only by passing immediately over the crest of the traverse, and falling down almost vertically at its base, which must be a rare chance for a shot fired according to the usual ricochet practice, with from six to nine degrees of elevation.

"Previously to the sieges in Spain, this nature of fire had been utterly neglected in England, and we were obliged to take its character on trust from the continental powers, who, finding the reduced charge most applicable to their brass guns, had an interested motive for vaunting forth its praise. We can now, however, correct our judgment by a course of practice carried on at Woolwich, under Colonels Sir A. Fraser and Dickson, and other practised artillerists, in 1820 and 1821, under very favourable circumstances.

"A face of a bastion of fifty toises in length, was armed with six guns mounted on garrison platforms, two in the centre of the face, and two at each extremity of the face; and on the flank of the bastion seen in reverse by the enfilading batteries, other two guns were mounted.

"The ordnance employed consisted of 24 and 18-pounder iron guns, 10, 8, and 5½-inch howitzers, and 68-pounder carronades. The face of the work to be enfiladed was on the same level with the enfilading batteries, and the parapet to be cleared eight feet in height. The distance from the battery to the work was accurately measured, and the effect of each round reported, so as to regulate the next discharge.

"Twelve hundred and thirty rounds were fired with shells or shot. Of 90 rounds fired from 24 and 18-pounders, at 400 yards distance, with a charge of powder of $\frac{1}{32}$d the weight of the shot, two thirds, or 60 rounds, fell into the work.

"At a range of 600 yards, the same guns fired 240 rounds, with charges from $\frac{1}{32}$d to $\frac{1}{20}$th the weight of the shot, out of which number 96 fell into the work, being between a half and one third of the number fired: at the distance of 800 yards, 150 rounds being fired with charges from $\frac{1}{24}$th to $\frac{1}{12}$th the weight of the shot, only 57 fell into the work, being a proportion between one-third and two-fifths.

"Of ten rounds of shot fired from 68-pounder carronades at 600 yards distance, with a charge of powder of $\frac{1}{34}$th the weight of the shot, four rounds took effect, and averaged five bounds each.

"Of ten rounds of shells fired from the same piece, at the same distance, with one pound eight ounces of powder, six fell into the work, and averaged six bounds each shell.

"This course of ricochet practice was commenced with the face of the work destitute of traverses: but after the range had been attained with accuracy, traverses of the rude and primitive construction, usually formed by a garrison on being attacked, were added.

"The shot fired before the work was traversed, made from 10 to 27 grazes along the terre-plein, being an average of 13 grazes each shot; but subsequently very few made more than a second bound.

"Of 170 shells, filled with powder, fired from the howitzers, after the work was traversed, 58 only bounded along the terre-plein, and of these 58, only 33 burst whilst bounding along the work, in consequence of the fuzes having been cut longer than necessary for the time of flight to admit of their lodging in the traverses previously to exploding. The 33 shells which exploded did much injury to the traverses; but no gun, so protected, was disabled during the course of the practice, though many guns were repeatedly struck, and some disabled, before the traverses were thrown up to cover them.

"From this course of practice it may be assumed, that about 400 yards is the best distance for an enfilade fire à ricochet—that such fire is to be preferred to any other, within the distance of 600 yards from the object, but that beyond 600 yards fully two thirds of the ammunition will be thrown away, and consequently ricochet fire can rarely be an advantageous employment of artillery, where precision is required, at any distance exceeding 600 or 650 yards. In the defence, however, when directed against the approaches and parallels of a besieger spread over an immence space, this nature of fire, from its bounding and grazing, must at all periods of a siege prove of great annoyance to the working parties and guard of the trenches.

"Ricochet fire would appear from these experiments to enjoy a reputation in the attack of places beyond its merit; and most probably, from the circumstance that in all regular and well-conducted sieges the enfilade batteries à ricochet are invariably seconded by a powerful fire of mortars on the faces and flanks of works, the artillery of which they are intended to silence; and the end being obtained, a degree of credit is given to the fashionable and favourite fire à ricochet, which ought, in justice, to be largely shared with the mortars, for the late experiments justify the belief, that, without the assistance of heavy vertical fire, an enfilade fire à ricochet cannot be rendered destructive along a face well traversed. Shells are absolutely necessary as pioneers, to level the protecting parapets, and gain scope for the more teazing, though less powerful efforts of the latter, and without their assistance it is almost harmless.

"It is not wished to disparage enfilade fire, or to praise direct fire at its expense. Direct fire is certainly irresistible where it can reach; it will cut through stone parapets, ruin embrazures, and destroy masonry defences of every nature; but it will not serve every purpose. There is no exclusive weapon in the science of attack and defence; it is neither vertical, ricochet, nor direct fire alone, but a judicious combination of the three, which will prove irresistible.

"*Enfilade Fire with Full Charge.*

"Experience has proved that an enfilade fire with the full charge of powder may be rendered extremely annoying to extensive and general lines of defensive works, and will sweep along them, making many bounds, from distances as great as 1,800 yards. Such batteries at the siege of Gibraltar gave great annoyance to the defenders of the sea-line between the Montagu and King's bastions; and General D'Arcon considered the failure of the Spaniards to maintain this fire with energy on the 13th September, 1782, to have been a principal cause of the defeat of his maritime efforts to breach the latter bastion.

"Against single lines, however, such as a face or flank, a shot fired from a distance to require the full charge has little chance of striking the terre-plein with precision, and no chance of making a second bound, where the work is properly traversed. Indeed, it is probable that its force would be generally spent on the traverses, which shells would far more powerfully destroy; besides which, spherical case fired from 24-pounders, at any distance exceeding 600 or 700 yards, to enfilade a moderate line, would be infinitely more destructive to the defenders than round shot.

"It would therefore seem that as means of *general* annoyance, where ammunition is abundant, it is desirable to erect enfilading gun batteries wherever practicable within 1,800 yards; but it is repeated that, where means are limited, and it is essential to success to make the most effectual and judicious use of the weapons and ammunition brought up, enfilade gun batteries to fire à ricochet should be prohibited beyond the distance of 650 yards."

192. From the sentiments of this eminent engineer, it appears that although ricochet fire enjoyed an undeserved reputation, yet, that, combined with direct and vertical fire, the guns on the faces of the defensive works are, even when well traversed, liable to be silenced from a distance: for, in the attack, (fig. 122,) the besieger occupies the great arc of a circle; and the besieged a small arc within it; so that, as the former has a choice of position, he can aline himself easily on the prolongations of the faces of the ravelins and bastions, where he can erect his enfilade batteries, and establish his direct and mortar batteries in situations best suited to assist them; so that the guns on the terre-pleines of the defensive works are exposed to a combined fire, that soon produces the effect of slackening their fire.

193. Some engineers, at the head of whom stands "*Montalembert*," have proposed to remedy this serious disadvantage, by making vaulted apartments of masonry for the guns, covered on top by many feet of earth, so as to be proof against the bursting of shells; or by placing the guns in batteries covered by carpentry work and earth, in which they have a certain extent of range, equal to the opening of the embrasure, while neither enfilade, ricochet, or vertical fire, can reach them.

194. Besides the guns on the terre-pleines of the ramparts being subject to the combined effects of all an enemy's batteries, the magazines, barracks, hospitals, storehouses, &c., being equally exposed to vertical fire, require to be proof against the effect of shells: for if the works of a fortress were perfect, and capable of offering a long and powerful resistance, but unprovided with bomb-proof cover for its magazines, &c., a bombardment from a distance of a thousand yards and upwards would suffice to reduce the place; against which the assailant would not fail to bring a sufficient number of mortars, and the means necessary to ensure the fall and ruin of such common buildings as might be appropriated for any of the above purposes. In treating, therefore, of bomb-proof cover, it is proposed to bring under one head all the buildings necessary for a well-ordered fortress, whether it be to secure the magazines, hospitals, and stores, or to furnish cover for batteries of guns, in which they can be placed in security from vertical fire and bombardment.

195. Bomb-proof buildings are usually long, narrow apartments of masonry, arched at top; the outer layers of masonry terminating at an angle above the arch. They are either isolated or made under the mass of the ramparts: in the latter case they are called *casemates.* It would be dangerous to lodge the powder in magazines under the ramparts, for, if an explosion took place, the rampart would be opened, and a breach thus made at once. Powder magazines are therefore isolated buildings, of a construction so solid as to resist the fall and bursting of shells; and they should be placed in situations as far removed as possible from the fronts likely to be attacked, and surrounded by every precaution to render them as little liable to injury or accident as possible.

196. The dimensions of one of Vauban's principal magazines are as follow: see figs. 50 and 51. The apartment *a. b.* fig. 50, is sixty feet long by twenty-five feet wide; the interior height of the wall above the floor is six feet where the spring of the arch begins: the long walls, or piers, *a. g.*, are eight feet

thick, strengthened exteriorly by four counterforts, *g*, *h*, *h*, *h* : the masonry is three feet thick at the thinnest part of the arch, and about eight feet at the angle over the key of the arch. The end walls are four feet thick; in one is a door and a window; and a window in the other: no iron is admitted into the construction, the doors and windows being lined with sheet copper: the floor is supported on lines of small brick pillars, so as to keep it dry, and give a free circulation of air under it: the magazine is ventilated by air holes, (*i. i, i*, figs. 50 and 51), cut in the side walls, so as to leave a solid die of masonry in its centre; and being further protected by perforated sheets of copper, nothing can be insinuated through these openings. Powder being a most delicate agent, and susceptible of imbibing atmospheric moisture, every means must be used to obtain good ventilation and equal temperature for it.

The powder is usually piled in tiers of three barrels: Vauban's magazine just described will thus hold one thousand and fifty barrels, or one hundred thousand pounds of powder. As a further security, the whole building is surrounded, at a distance of twelve feet from its walls, by a wall of ten or eleven feet in height; *d d*, figs. 50 and 51.

197. The following is extracted from the second vol. of Col. Pasley's Course of Elementary Fortification, page 374.

"In our magazines in the British dominions, the arches have never been made so wide as the above (*Vauban's*); and, therefore, whenever a considerable interior capacity was required, the body of the building has generally been formed of two or more arches, connected together by intermediate doors or passages left in the piers."*

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* In two powder magazines of equal length and interior capacity, and whose arches are of equal thickness, that which is formed with one very wide arch is weaker than another formed of two smaller arches; because the strength of an arch, like that of a beam of timber, is diminished in proportion to the distance between the piers that support it.

"For example, in Upnor magazine, near Chatham, there are four arches, each eighty-eight feet long by nineteen feet wide, in the clear, with piers four feet thick; abutments of ten feet, and end walls equal to the piers in thickness. The height from the level of the floor to the spring of the arches is nine feet and a half; and the latter, which is in the form catenarian,* have a rise equal to half their span, are three feet thick. The total depth of masonry at the crown of the arch is seven feet. In every pier there are five interior doors or passages of communication arched at top, each five feet wide by seven feet high. Each division of this magazine has one door and window at each end, besides which there is one door in the centre of each of the abutments or side walls. There are twenty air holes in the body of the magazine; eight of which are pierced in the end walls; besides which, there are sixteen air holes leading from the outside of the building below the floor.

"The roof is formed of paving tiles laid in common mortar upon the masonry of the ridges, the gutters only being leaded. This powder magazine will hold conveniently about ten thousand barrels piled in tiers of nine barrels high." That is, at ninety pounds per barrel, nine hundred thousand pounds: Col. Pasley adds, "that the construction of Upnor magazine has in general, been very highly approved, it being dry and commodious."

Besides the principal powder magazines, there are smaller ones distributed amongst the works, termed *expense magazines*,

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Vauban's plan was therefore explained, not as being a good model to follow in practice, the arch being certainly too wide, but from the circumstance that experience has repeatedly proved it to be bomb proof.

* When a chain is suspended between any two fixed points, it forms a peculiar curve, the chord or span of which may be made to bear any given proportion to the height, by increasing or diminishing the length of the chain. The curve thus formed is called the catenarian curve, which, on comparison, will be found to differ very little from a regular parabola of the same span and height.

to serve for the daily expenditure of the garrison; they are also made bomb proof and of smaller dimensions, than the above. The recesses in the posterns as *c c* fig. 54, are secure places for ammunition; although too far removed from the service of the guns to answer the purpose so well as an expense magazine in the work.

198. *Casemates*, or bomb proof apartments for the accomodation of troops, for hospitals, store-houses, bake-houses, &c. are constructed under the mass of the ramparts of such portions of the works as are most suited for them. Fig. 52 is a longitudinal section, and fig. 53 a tranverse section, of a casemated rampart: the vault (*a b*, fig. 52) running the whole length of the rampart, and having a breadth (*c d*, fig. 53) sufficient for the purposes for which it is wanted: if for barracks or hospitals, it must be wide enough for two ranges of soldiers' cots or beds, with a passage down the centre of the apartment; if for a single gun, as *b*, a less breadth will suffice: in the former case, eighteen feet is the usual width, and in the latter eleven or twelve feet; the interior earthen slope of the rampart is suppressed, and a perpendicular wall of sufficient strength is substituted for it. The right half of fig. 52 is a view of the casemates as seen from the inside of the work: each apartment has a door and two windows facing inwards; and, at the other end, there are either embrasures *b*; loop-holes *e*; or windows *f*; according to circumstances: the ridges *i i* of the masonry are carefully finished, leaded, and covered with shingle, before the earth is thrown on, that it may be kept dry, and drained by the water pipes *o o*. Doors of communication are made in the piers that separate these vaulted apartments, as well as fireplaces in climates that render them necessary. To be useful healthy barracks, they must be well ventilated, and not too much crowded.

199. The following paragraphs are taken from Colonel Pasley's second volume of a Course of Elementary Fortification, page 371.

" The dimensions of some casemates, which have actually been executed, are as follows:

1st. The casemates in the left demi-bastion of Fort Ricasoli, in Malta, are thirty-five feet eight inches long, by twenty feet six inches wide. The piers are seven feet thick, with two doors of communication in each, and five feet six inches high, up to the spring of the arches, which are semicircular. There are embrasures at the height of two feet four inches above the floor, the interior dimensions of which are two feet three inches in width, by three feet high; their exterior dimensions being seven feet in width, by four feet three inches in height. The thickness of the scarp wall through which they are pierced is six feet eight inches. An air hole, nearly vertical, is cut in the arch of each casemate, towards the front of it, the dimensions of which are one foot nine inches, by two feet, at top, and four feet six inches, by five feet, at bottom. These casemates are open in rear, with the exception of a thin wall raised three or four feet only above the floor. Seven of them contained heavy guns, which, for the sake of experiment, were fired five or six times as quick as possible; and the smoke was found to go off pretty freely.

" 2d. The casemates in the King's and Orange bastions at Gibraltar have, by long experience, been found good healthy quarters for troops. They are all about sixteen feet wide, and of the same height up to the crown of the arches, which are semicircular. The piers are about five feet thick, with a door of communication in each. The King's bastion casemates are about forty feet long, and have no openings in the scarp wall in front, nor any air holes to produce a thorough draft. The Orange bastion casemates are about ninety or one hundred feet long, each having two narrow loop-holes in front towards the bay, and three vertical air holes cut in the arch, which at top are only about four or five inches wide.

3d. " The casemates in the new counterguards at Gibraltar are sixteen feet wide, and of various lengths, according to the width of the rampart, which is irregular. They are about six feet high to the spring of the arches, which are segments of ninety degrees. They have embrasures in front, and a door of communication in each pier.

"In some new casemates, which I am informed have lately been constructed at Gibraltar, the width is eighteen feet, which may be considered a more convenient dimension for the accommodation of troops.

"4th. The casemates at Cumberland Fort, near Portsmouth, have been inhabited for many years. They are each thirty-eight feet long by fourteen feet wide: the piers are five feet thick, with two doors of communication in each, and five feet high up to the spring of the arches, which are segments of 120° nearly, their rise being 4 feet. In each casemate there is a fire-place, and either an embrasure or loop-hole in front. The average depth of the crown of the arch below the level of the terre-plein is about seven feet six inches. The new casemates, constructed at Southsea Castle, have also arches of 120°.

"5th. In the casemated cavalier, near the left of Chatham Lines, the soldiers' casemates are sixty-one feet long by seventeen feet wide: they are two stories high: the height of the lower story is ten feet below the joists, which support the wooden floor above it: the height of the upper story is eleven feet from the floor to the crown of the bomb proof arches, which are semicircular: the piers are four feet thick, with one door of communication cut through each of them in the upper story, and three air-holes in the lower one: the abutments are nine feet thick: the front and end walls of the lower story are sunk in the terre-plein of the lines. In both stories are fire-places, and the upper rooms have loop-holes in front, one on each side of the fireplace. A gallery of wood, supported by brick piers, runs along the whole extent of the lower rooms, the top of which, being secured by a proper railing, serves as a corridor for the upper story, and is ascended by a flight of steps at each end. A gallery of the above description, or rather one arched over at top, for greater security, is very useful in all casements built with two stories; for it not only affords the most convenient mode of communicating with the upper story, but serves also as a place of parade for the men in bad weather.

"6th. In the fortifications constructed on the Western Heights of Dover, the principal casemates are seventy-seven feet long by eighteen feet wide: the piers are four feet one inch thick, with a door of communication in each, and eight feet high up to the spring of the arches, which are parabolical, and have a rise equal to half their span. There are three fireplaces in each casement, and one embrasure in front.

"The whole of the above described casemates, excepting those of Fort Ricasoli, are inclosed by a back wall, having a door and windows."

209. In Note 51, Vol. 2, of Sir John Jones's Sieges, there is a relation of the surrender of Fort Bourbon, at Martinique, in 1809, which is remarked as "being a solitary instance of a place purely military, and garrisoned by good troops, surrendering under the terrors of a bombardment, whilst the works remained entire;" in consequence of the "effect produced by shells on the magazines, armament, and artillery buildings.

"The British troops, about nine or ten thousand men, landed on the 30th January, 1809, and on the evening of the 19th of February, had thrown up batteries, which opened with eighteen mortars, five howitzers, and sixteen guns on the fort. This number of pieces of ordnance, fired indiscriminately into the place till the 24th, when the governor capitulated."

Then follows a statement of the actual condition of the magazines, artillery, store-houses, and armament of the place, at the moment of surrender, signed by a Captain of the French and of the British Artillery.

"From the statements of the governor on his trial, confirmed by this report, it appears, that three magazines exploded during the bombardment, that the arches of the gateways were broken through, and that the fort was given up through apprehension of the principal magazine, containing three hundred thousand pounds of powder, being also blown up, the besiegers' shells having penetrated through some inches of the masonry.

"As the arches thus broken through and damaged are stated to have been of the customary thickness of three feet, it would be natural to conclude that such thickness is not sufficient; but a thousand instances attest, that a well-turned arch, of three feet in thickness, of the span of eighteen feet, resting on sufficient piers, and being covered with five feet of masonry and earth, will resist the heaviest shells: at least, the magazines of Vauban, of nearly similar dimensions, were always found sufficiently strong in the war of succession, and at the sieges between 1744 and 1748.

"The strength of masonry is far greater in southern than in northern climates*, whilst the concussion produced by the fall of shells at equal distances and of equal weights, must be the same in all climates and in all ages: why, therefore, do arches of magazines give way more frequently now than in former wars? It can only be accounted for from the fact, that in proportion that one shell was fired into a place in those days, we in our bombardments throw fifty into a place. Substance is now required much beyond that essential for strength. It is not sufficient that an arch have all the requisite proportions to resist the shock of the heaviest shell, and the piers of a force to bear it up, or the roof a pitch to keep it dry; it must also have bulk over it to admit of the repeated abstractions of substance, caused by numerous shells striking it in rapid succession. Each shell blows away a portion of the covering of the arch, and if their fall be so continuous as to prevent fresh covering being laid on, they speedily penetrate to the masonry; after which each

* The author (Sir John Jones) once had in his possession a memorandum, made on the spot by an officer, that an arch of eighteen feet span, and two feet nine inches thick, without any covering, resisted two shocks of thirteen-inch shells successively, at the siege of Fort George in Minorca.

shell carries away two or three inches of the thickness of the brickwork, and in a few rounds the equilibrium of strength of the arch is destroyed. As soon as that is effected, a shell striking any part of the surface, shakes the arch through and through, and after a time it is broken down."*

"That a bomb proof arch should be kept extremely well covered, is therefore fully as important to its resistance, as that sufficient dimensions be given to the arch itself. Officers in future, must take precautions against the increased use of artillery of the present day, and no longer trust to dimensions derived from the experience of the wars of Lewis XIV. In small places, like Fort Bourbon, no magazine should have less than eight or ten feet of masonry and earth over its arch; and every governor, during a bambardment, ought most sedulously to enforce the immediate restoration of every portion of earth blown away by the fall of shells."

201. From these recorded sentiments of Colonel Pasley and Sir John Jones, it would appear that Vauban's dimensions are two weak to be trusted to for isolated powder magazines, under the present encreased effects of vertical fire; and that when circumstances admit of having their roofs covered with seven or eight feet of earth above the masonry arches, it is a safer construction than plain masonry of sufficient strength: for a shell falling with its full gravity, penetrates about three or four feet into the earth; therefore, if the arch of a powder magazine can be thus covered, the shock of the shell falling on it will be greatly deadened ere it can reach the masonry: and, if the defenders be on the alert to fill up all the holes as soon as they are formed by the falling and bursting of shells, the bomb proofs can thus be rendered quite secure.

But when a powder magazine has to stand alone without any covering of earth, as that of Vauban, represented in figs. 50 and

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* A heavy shell, falling on a bomb proof arch well covered with earth, has been known to cause such a concussion as to make wine glasses jump off a dinner table in a casemate, without injury to the arch.

51; the masonry in the thinnest part of the arch should be four feet; and over the crown, nine or ten feet; with piers of sufficient strength to support the arch; and, in moist climates, of a steeper pitch than Vauban's.

202. It now remains to show the parts of the works most suited for the construction of casemates: and for that purpose, it is necessary to remark that, when the enemy has established his breaching batteries against a revêtement, where the rampart behind it is hollow from casemates, as soon as a breach is formed and the arch and piers of the casemates destroyed, the mass of rampart and parapet above them, will sink down and lay open the space within, to the level of the ground. It is true that the breaching batteries may find some difficulty in destroying good strong arches and their piers, but when done, the evil of the whole of the ground behind the casemated rampart being quite exposed, is very great. It is therefore recommended to construct casemates under such parts of the ramparts as are the least exposed to be breached.

Now, on a regular front, provided with a good tenaille, the face of the bastion is the only portion of the enceinte, the revêtement of which, the enemy can see sufficiently low down to make a practicable breach, (paragraph 62). The flanks and curtain are therefore the most eligible for casemates; where these apartments can be made under the whole breadth of the rampart, and have loop-holes or windows in the escarp, which will give them a healthy ventilation; for the tenaille would prevent an enemy seeing these openings: see fig. 36, *o o o*, the casemates in the flank and curtain covered by the tenaille *t*. (The left half bastion of fig. 36, is empty, and the right half is full).

Casemates are sometimes made in full bastions, as *a b c* fig. 36, and also to run partially through the revêtement of empty bastions, as *d f* fig. 36: but in these cases, the bomb proofs are never so pleasant or healthy for troops, for want of ventilation, as when made, (as seen in fig. 52), to run through the whole of the rampart: nevertheless, when the revêtements are exposed to be breached, it is better to have a solid mass *e e*, fig. 36, behind the wall, than to have the casemate through its whole length.

Cavaliers being covered in front by the faces of the bastions, afford the means of making good casemates under them, especially when the rampart of the cavalier follows the windings of the faces and flanks, leaving the interior hollow; as then the casemates can be easily ventilated by being made through the whole width of the rampart. The curtain cavalier, mentioned in paragraph 155, offers an excellent situation for the construction of good casemates; see fig. 22.

When bastions are covered by counterguards, as seen on the bastion *a*, fig. 25; or ravelins by counterguards, as *t*, fig. 25; so that the enemy's breaching batteries on the covered-way cannot see their revêtements; their ramparts are proper for the construction of casemates: likewise a great portion of the rampart of the ravelins in fig. 27, which are covered by the tenaillons and demi-tenaillons.

The inaccessible fronts of a fortress, especially when facing the sea, are choice situations for casemates, as barracks, hospitals, &c.*

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* Casemated batteries having the terre-pleine of their ramparts above crowned with guns en barbette; or rather on traversing platforms, (Definition 23), are formidable defences for the entrance of ports, harbours, rivers, &c.; especially when they have an elevation superior to that of the decks of ships passing them: but in deep water, where ships can approach near to batteries, *à fleur d'eau*, or level with the water, they can concentrate such a heavy, near fire, on a single point, as to overwhelm the landsmen, and drive them from their guns.

If the nature of the coast does not permit ships to run up alongside a land battery, very few guns will be an overmatch for a line of battle ship; for every shot from the land battery tells on the wooden walls, and if red-hot shot (with the means of obtaining which, land batteries on the coast are usually provided), a very few rounds may serve to decide the contest: here the guns are carefully pointed through, or over, earthen parapets, and incorrect practice is quite inexcusable; but whole broadsides fired from ships of war, from unsteady platforms consequent on the motion of the ship; and from five, six, or seven hundred yards distance, With respect to casemated batteries, their situation must depend entirely upon where they would be most useful: that is, where they are wanted to flank ditches, causeways, &c., that would otherwise be without a proper defence.

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must, of necessity, be quite uncertain. This has been abundantly proved during the last war. In note 43, second vol. of Sir John Jones's Sieges, it is related, that "Sir Sidney Smith, in the Pompee of eighty guns, with two frigates, anchored about eight hundred yards from a battery of two guns on the extremity of Cape Licosa, and protected from assault by a tower in which were twenty-five French soldiers, commanded by a lieutenant. The line of battle ship and the frigates fired successive broadsides till their ammunition was nearly expended, the battery continually replying with a slow but destructive effect. The Pompee, at which ship alone it directed its fire, had about forty shot in her hull; her mizen top-mast carried away; one lieutenant, one midshipman, five men killed, and thirty men wounded: at length, force proving ineffectual, negociation was resorted to; and after some hours' parley, the officer, a Corsican and relation of Napoleon, capitulated. It then appeared that the carriage of one of the two guns had failed on the second shot, and the gun had subsequently been fired lying on the sill of the embrasure; so that, in fact, the attack of an eighty gun ship and two frigates had been resisted by a single piece of ordnance." The pupil is referred to this note, which shows "that the comparative effect of fire from ships afloat, or from batteries ashore, is altogether dependant on distance." Another instance of the superiority of a land battery over a ship is detailed in the United Service Journal, No. 46; "The small army that, under Lord Lynedoch, advanced towards Antwerp, early 1814, established a post in a head formed by the Polder Dyke, at some distance below Lillo. The place is called Fort Frederick, though showing no appearance of fortification beyond the barely visible site of two embrasures; one of these was at a right angle with the course of the river, whilst the other looked diagonally up the stream. A long eighteen pounder was placed in the first, and a five and a half inch howitzer in the second. From this post the French determined to dislodge us; and on a very fine and calm morning, an eighty-four gun-ship dropped down with the tide, and anchored near the Flanders shore, about six hundred yards from the British battery: by her position she was secured from the fire of the eighteen pounder, and exposed to that of the howitzer only. As soon as every thing was made tight, her broadside opened;

In the citadel on the western heights of Dover, the parapets are solid, and without embrasures, the guns being mounted on traversing platforms (definition 23); and the ditches chiefly defended by casemated batteries; the embrasures of which are so near the bottom of the ditch, that to prevent access to them, an additional cut or drop is made in the ditch before them.

It may be remembered that the left branch of the horn work (fig. 28) is of an equal depth from *e* to *i*, and that it is proposed to defend it by a casemated battery *i*, the entrance into which is from the counterscarp of the ravelin *s*; and without this provision the ditch of the branch would be in a great measure undefended.

203. The engineers who have advocated, and written largely on, the advantages of covering both guns and mortars in casemates where they can act undisturbed by either the vertical or ricochet fire of the enemy, have generally pushed their favourite theory too far, and fallen into complicated and expensive constructions in order to obtain their object. The splendid casemated systems of General Montalembert are too extensive to be more than cursorily noticed in a treatise of this nature; and the more recent casemated method of Count Carnot, for vertical fire,

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and if noise and smoke were alone sufficient to ensure success in war, as so many of the moderns seem to think, the result of this strange contest could not have been long doubtful; for the thunder of the French artillery actually made the earth to shake again; but though the earth shook, the single British howitzer was neither dismounted nor silenced; and though the artillerymen could not, perfectly exposed as they were, stand at their gun whilst the iron hail was striking thick and fast around, yet no sooner did the enemy's fire slacken for a moment, than they sprang to their post, ready to return at least one shot for eighty. This extraordinary combat lasted from seven o'clock in the morning till twelve at noon, when the French ship, having had forty-one men killed and wounded, her commander being in the list of the latter; and having, besides, sustained serious damage in her hull and rigging, returned to whence she came, without effecting any thing whatever; for the howitzer was not dismounted, the fort was not injured, and the British lost only one man killed and two wounded."

is sufficiently exposed in a luminous note in the second volume of Sir John Jones's Sieges: in this note, however, there is the following remark: "but if he (Count Carnot) has failed in tracing a perfect front, founded on the basis of Montalembert's system of casemated and reverse fire, he has by the attempt rescued a valuable suggestion from unmerited neglect on the continent, and rendered an important service to science, by directing the attention of military men to the means most likely to create a barrier against the growing powers of the attack." From this it would appear that Sir John Jones looks to a good casemated system as the probable means of neutralizing the powers of the attack; and, if this mode of defence be extensively applied, it will naturally lead to a tracing different from that of the bastion system. As a single instance of this kind, suppose the flanks of the bastions (in fig. 14) to be armed with casemated batteries; the tenaille must then be suppressed, else it would altogether mask their fire; neither would there be any necessity for such a length of curtain (paragraph 26), as the guns of the casemated batteries on the flanks would be only a few feet above the level of the ditch, and could easily defend it. Now Montalembert, in his system *tenaille casematée*, proposed to suppress the tenaille and curtain (as in fig. 37); to prolong the faces of the bastions; and to join them by the two flanks to the faces of the redoubt of the ravelin: one hundred toises of rampart will thus be saved; the flanks will be better covered than they are in Vauban's systems, the fire will be more certain, and the line of defence will be shorter. But, if the same line of defence be preserved by prolonging the faces, an exterior side of three hundred and sixty toises can be obtained, which would enclose, as an heptagon, a space equal to a dodecagon of one hundred and eighty toises exterior side; from which would result, with an equal defence, an economy of one thousand three hundred and thirty-six running toises of rampart of the enceinte; to this add the suppression of five demi-lunes and their redoubts, making a total of eighteen thousand nine hundred and twenty cubic toises of masonry, less than in a dodecagon. The author then goes on to multiply his works, and apply the masonry economised to a beautiful system of casemates for batteries and accommodation.

This hint of the nature of a casemated system is sufficient to show that it would be impossible to enter upon the consideration of it here; and as existing fortresses are laid out in the bastion method, it is of less consequence. Those desirous of further information are referred to the works of Montalembert and Carnot. In Mandar's fortification, there is an interesting sketch of the construction of the former.

204. Casemated batteries are objected to,

1st. Because they weaken the rampart under which they are constructed; and that, when their arches are ruined by the breaching batteries of the assailant, the whole mass of rampart and parapet above sinks down into the casemate, and exposes the interior of the work.

This is true, and has been already noticed.

2d. Because, in firing, the interior of the casemate is so soon filled with smoke, as necessarily to render the practice very slow, that time may be given to allow the smoke to clear away between each round; otherwise, the gunners would be forced to leave the casemate. In answer to this objection, it is said, casemated batteries are recommended to be made open in the rear; and when so, as well as being provided with good air holes, the smoke clears away quickly enough for all necessary purposes.

By paragraph 199, the casemates at Fort Ricasoli, though partially closed in rear, allowed the smoke to go off pretty freely. If this evil were as great as is generally asserted, when proper ventilating precautions are taken, how could quick and correct firing be carried on in ships of war?

3d. Because the splinters detached from the cheeks of the embrasures, and from the interior walls of the casemates, by an enemy's firing at and through these embrasures, are very destructive to the men serving the guns.

This is, indeed, a most serious objection; for, if casemated guns can command the country, they can also be seen from a distance; and, as the choice of position is with the assailant, he can readily find situations for his batteries, whence his guns can see the cheeks of the casemated embrasures, though the guns in these casemates cannot be brought to bear upon him; the assailant can thus batter the cheeks with shot that will probably bound through the embrasure into the casemate, to the destruction of the gunners. Of the evil resulting from this the following quotation from Sir John Jones's Sieges, vol. ii., is ample proof. It refers to the attack and capture of the castle of Scylla, in 1800, by part of Major General Sir John Stuart's army, then in Calabria, in conjunction with Sir Sidney Smith, in the Pompee of eighty guns.

"On examining the interior of these casemates, whilst the terms of surrender were still copying out fair, and, consequently, before steps could be taken to clear or purify the castle, it was altogether surprising to observe the mischief which had been produced by shot which had deflected from the cheeks of the embrasures, and entered the casemates.

"To judge from the indentations on the walls, and the marks of slaughter and destruction which every where presented themselves, a direct fire into a casemated embrasure of the usual construction must render casemated batteries untenable: indeed, in this attack, the French loss was chiefly by shot, which entered at the embrasures, and passed through the rear of the casemates. Such batteries should, therefore, be confined to situations where the embrasures can only be seen in the direction in which the guns they shelter can be pointed; or else the engineers ought to guard against this action of shot deflected from the cheeks, in the construction of the embrasures, which surely would not be difficult to accomplish where the fire of the batteries is, as in most works of defence, for a specific and limited object. Or, perhaps, it would prove more effectual, and it might be accomplished in most situations where direct fire only is required, such as on a causeway, the entry of a port, or a particular tongue of land, to cause the gun to fire through a second opening made in a screen in its front, and then no shot could by any possibility strike the embrasure, unless fired perpendicularly to the two openings."

205. With regard to blinded batteries, it is merely proposed to state what they are, without dwelling upon their construction; to blind a battery, is to drive a line of strong wooden uprights into the earth, running back about eighteen feet from the crest of the parapet, between every gun; these are a few inches higher than the crest, and connected at top by strong beams, on which a floor is made, sufficient to bear up a covering mass of earth of about four or five feet thick; this roof projects over the necks of the embrasures about six feet, being well fastened to the merlons: so as to form a complete cover for the guns and gunners; open in the rear; and, if not exposed to enfilade or ricochet, open likewise, at the sides, to obtain a ready ventilation for the smoke.

From what has already been said of the effects of shells, and the strength necessary to give to arched roofs of masonry, to withstand their shock, it is clear that the roofs of blinded batteries could not resist the fall and bursting of bombs: as bomb proof cover they are therefore defective: but in low situations on a river or the coast, they are efficient to protect the gunners against the fire from ships' tops in passing the battery.

CHAPTER IX.

Mining; blasting: defensive advantages to be drawn from water.

206. *Mining.* That the subject matter may be as little interrupted as possible, it is proposed to begin with the following *definitions* of such terms, as are commonly used: they are numbered for the benefit of references.

One. The subterranean excavations that are made under the ramparts, ditches, and glacis, in order to retard the enemy by blowing up his lodgments, or troops; are countermines: those used by the attacking party are called *mines*. It is better however to designate them by the terms *defensive* and *offensive mines*.

Two. The recess in which the powder is lodged, is the *chamber*: and the passage leading to it, is the *gallery*.

Three. Galleries are of three kinds: either *great galleries*, *galleries*, or *small galleries*, according to their dimensions.

A great gallery is seven or eight feet high, by five or six feet wide, in the clear.

A gallery is six feet high, by four or five feet wide.

A small gallery is three feet broad, and about four feet and a half high,

In the first, three or four men may pass each other; in the second, two can pass abreast of each other, walking uprightly: the last is intended only for one man at a time to pass, and he must stoop.

In prepared countermines, the galleries are lined and arched with masonry. In offensive mines they are supported by timber frames and planks.

A gallery frame is of an oblong shape of strong timber, like a door frame; the long uprights are the *stanchions*; the upper cross piece the *capsill*; and the lower cross piece, the *groundsill:* these frames stand a few feet from each other; and the top and sides of the gallery between them are supported by *roofing planks, or top sheeting;* and *side planks, or side sheeting.*

Four. The chamber is usually of a cubical form; and is made a little larger than the *coffer* or *powder box* containing the powder: there always must be a passage or gallery leading to the chamber; and on firing the powder, its explosive force would find vent through this passage were it not blocked up: this blocking up of the gallery is called *tamping:* it is done by sand bags, rammed earth, beams of wood, &c.; to an extent sufficient to create a greater resistance to the elastic force of the fired gunpowder, in the direction of the gallery, than it would experience in the direction of the enemy's works to be blown up. The chamber is not made on the line of the extremity or head of a gallery; but a branch or small gallery is run out a few feet right or left, as required, and the chamber formed at its head, (as in fig. 59: *b* the branch, c the chamber): the tamping then fills up the branch, and the struts that secure it, are firmly fixed against the outer side of the gallery. When the chamber is thus formed, the action of the fired gunpowder is not so great towards the gallery, as if the powder were lodged in a chamber directly at the head of the gallery.

Five. Through this tamping, runs a *powder hose or saucisson,* to communicate from the charge to the spot from which it is to be fired: this train or hose is generally lodged in a wooden case or *auget* to preserve it from damp or injury.

When ready for explosion; that is, the charge in the coffer box; the tamping completed, and the train laid; a piece of port fire of sufficient length is attached to the end of the hose, which, taking some minutes to burn, allows the man that lights it, to escape.

Six. If a mine *A,* fig. 56, placed at a certain depth, in ground of equal tenacity, be feebly charged, its effect is confined to an interior spherical rupture, the radius of which is proportional to the charge: this smothered mine *m n o*, is what miners call a *camouflet,* and is used in subterranean war, to stifle a neighbouring enemy at work, or to break in his gallery, without affecting the upper surface of the ground.

Seven. If the charge be sufficient, the elastic fluid generated by the explosion, experiencing less resistance above than laterally, will raise the earth and form a *funnel* or *crater*; the radius of which will depend upon the charge. A line drawn from the centre of the charge to the nearest surface where this crater would be formed, is *the line of least resistance,* as *a b*, fig. 57.

Eight. When the charge is sufficient to produce a crater, the radius of which is equal to the line of least resistance, it is an *ordinary charge,* as $bc = ab$, fig. 57; or the diameter *ed* is double the line *a b*: it is also called a *two-lined charge and crater*. Should the charge give a crater, the diameter of which is equal to three times the length of the line of least resistance, it is *a three-lined charge and crater*; and so on. A mine loaded with a very great charge of powder is termed a *globe of compression*.

It is said that a charge which can produce a six-lined crater will ruin galleries at a distance of even more than four times the length of its line of least resistance. Globes of compression are, therefore, more resorted to by the besieger than the besieged, in order to destroy the galleries of the defensive mines.

Besides the visible effects of the discharge of a mine, as shown by the shaded crater *d a b*, fig. 57; the disturbing or compressing effects of it on the adjoining soil may, when that soil is of common tenacity, be represented by the elliptic *c e f g d*, fig. 57; and, in an ordinary mine, the dimensions in this figure would be (taking the line of least resistance as 1)

$$ab=1: \quad ag=1{\cdot}7: \quad af=1{\cdot}3: \quad dc=2.$$

In fig. 58, let the shaded crater *d a c* represent the maximum opening produced by a mine charged with twelve times the quantity of an ordinary mine; the compressed ground (and hence the name globe of compression) is shown by the curved line *d g f e c*: this compression, in the direction *a f*, increases but little with the increase of charge; but laterally, towards *g* and *e*, it extends considerably as the charge is increased: in this case, taking the line of least resistance at 1, the dimensions would be as follows:

$$ab=1: \quad ag=4{\cdot}6: \quad af=1{\cdot}4: \quad dc=6.$$

The small mines usually employed to defend the unflanked ditches of field works, &c., and which are sunk from three to eight feet below the surface, are termed *fougasses*.

The labour of constructing a gallery and chamber for a fougass is generally dispensed with; and a trench is sunk from the surface, the charge is laid in it, and a saucisson, or powder hose, conducted from it; and the earth is filled in again.

Nine. In the construction of a system of defensive mines, it is usual, first, to trace the width and direction of the galleries upon the surface of the ground; and then to sink square or rectangular wells or *shafts*, to gain the required depth. The ground underneath the covered-way and glacis is divided into compartments by the galleries that cross and traverse each other; and the shafts are usually sunk at the spots where the galleries are intended to intersect; that, in *driving the galleries*, in the required direction, from the bottoms of these shafts, the miners may have the benefit of as much air as possible from them. In driving a gallery, the air becomes so bad at eighty or ninety feet, that candles will not burn, and the miners cannot respire. Should miners be working towards each other in the construction of a system of mines, the shafts should not be at a greater distance from each other than twice the above; that is, about one hundred and sixty or one hundred and seventy feet from shaft to shaft.

In a system of countermines, the entrance into the main galleries is usually through the counterscarp revêtement, which is more convenient than shafts, and affords more light and air.*

207. A system of prepared countermines upon weak fronts, if known to the assailant, may influence him to form his attack against stronger fronts, rather than encounter the delays of a subterranean war, in which he cannot proceed with his offensive

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* At the field engineer department at Chatham, Colonel Pasley has introduced a method of ventilating galleries of any length, by forcing air from a pair of bellows, made of a cylinder of pliable leather, into a long pipe which is conveyed to the head of the gallery: the bellows is about a foot in diameter and a foot in depth, having a circular wooden top and bottom: the air enters by a valve in the wooden bottom, and is forced into a pipe attached to one side: to this pipe, others of leather, and from three to five feet in length, can be fixed on successively, having tin tubes at each end, tapered to fit tightly into each other; these pipes are about one inch and a half in diameter, and being always led to the head of the gallery, fresh air is pumped in continually from the bellows, which is worked at the shaft.

works above ground until he has felt for the countermines, and secured the ground below*. And although the powers of the attack in this branch of warfare are greatly superior to those of the defence, in consequence of the effects of globes of compression, as well as the discovery that an excess of charge will do away with the necessity of putting the usual weight of earth over the powder, and thereby save much labour in the construction of offensive galleries; yet countermines call for the execution, and consequent delay, of all these offensive means.

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* In fig. 29 the small circles *x*, *x*, *x x* are intended to show the countermines, prepared by the French engineers, to aid in the defence of the most accessible fronts of Badajoz, when this fortress was attacked by the Duke of Wellington in 1812. The French commanding engineer, Colonel Lamare, in his relation of the defence says, with reference to fronts *k a*, *a b*; "And as there was reason to suppose that they would be chosen in preference as the point of attack, we prepared in front of them every means of defence, which the time and our resources could afford. For this reason we formed galleries and branches *x x x* at each salient of the counterscarp, in order to be able, in case of necessity, to form mines under the breaching batteries, and afterwards to sink shafts for other mines in the terre-pleines of these bastions, for the purpose of destroying the works in proportion as the enemy should gain them, and leaving only a heap of ruins if he should succeed in making himself master of the place, after the garrison should have retired into the castle." In the relation of the attack on this occasion, by the English engineer, Colonel Sir John Jones, at page 163, vol. i. of his Sieges, the following sentences are found: "On reconnoitring the place, it was found that the French had strengthened it very considerably since the attack of last year," &c. &c.—"They had also countermined the three right fronts," &c.—"And without miners, without mortars, and having only inexperienced sappers, and a most inadequate number of guns, to attack the south fronts, which were countermined, and would necessitate three or four lodgements being formed, could not be recommended."

Here, then, is one fact in confirmation of the above assertion, that countermines on weak or accessible fronts, have sometimes the effect of inducing an enemy to form his attack against fronts more formidable or difficult of access; as in this case, from want of an efficient siege establishment to attack the most open fronts, the British preferred attacking the eastern fronts *ef*, *fg* covered by the strong redoubt Picurina, the stream Rivillas, and its inundation.

208. Messrs. Gumpertz and Lebrun, in their excellent treatise on mines, have clearly shown, that defensive mines should be situated in the same plane, or nearly on the same level, below the surface: that since the invention of globes of compression, the systems of having mines on different levels are no longer applicable. These complicated and expensive arrangements, of having different stages of mines under the enemy's feet, were intended to overthrow the same ground several times: but as globes of compression can destroy galleries at a distance equal to four times the length of their respective lines of least resistance, several of these stages would assuredly be destroyed from one explosion of a surcharged mine, or globe of compression. The opinion, however, of these engineers that the galleries should be so far below the surface as to prevent an enemy getting beneath them, is not so much approved of; since galleries at a moderate depth are not more exposed than by going lower, while they secure a triple advantage: 1st, economy in the consumption of powder; 2d, as they can be constructed by sinking trenches down to the required level there will be less labour, and when charged they will require less tamping; 3d, the facility of keeping the galleries dry, by the slope that can be given to them to the rear.

For these reasons it is proposed in this treatise to explain a system of simple countermines, placed at a moderate depth below the surface of the ground.

209. *Description of the galleries.* The principal, or *magistral gallery*, or, as it is more frequently called, *the gallery of the counterscarp*, which serves as the base of a system of countermines, is represented in fig. 59, by the double shaded line *A B C;* that which is parallel to it, and beyond it, *D E F*, is *the envelop gallery;* those that connect these parallel galleries, as *m n*, are *galleries of communication;* and all those pushed into the country beyond the envelope gallery, as *q q q*, are *listening galleries.*

210. *The counterscarp, or magistral gallery.* Its situation in some systems is immediately under the banquette of the covered way; in others, under the terre-pleine of the covered way; and, in some, immediately behind the counterscarp revêtement: the last is generally considered the best situation for it, (as seen in figs. 59 and 60): as masonry is thereby economised, for the revêtement itself forms one side of the gallery. The gallery also is better lighted and aired by the doors and loop-holes looking into the ditch, (see fig. 60); and, lastly, it is as far removed as possible from the terrible effects of the enemy's globes of compression. In this situation it is more especially called the counterscarp gallery.

In the construction of the counterscarp gallery the revêtement is usually built without counterforts, as in fig. 60; but it becomes necessary to thicken the portions of this wall that have to support the pressure of traverses, as at *t t;* so that the gallery is not in one continued line, but passes immediately round the back of the counterscarp revêtement, following its shape. In the thinnest part of this revêtement, loop-holes are pierced in order to get a reverse fire of musketry into the ditch, as well as to light and air the gallery. Strong massive doors secure the openings into the ditch, through the counterscarp; these are made opposite to the galleries of communication. Small magazines, *a a*, fig. 60, are formed in considerable numbers, principally at the entrances of the galleries, to contain the miners' tools, timber for forming branches, sand bags, &c., used in tamping; the best and driest of these recesses are used as magazines for the powder required for the mines.

The counterscarp gallery has always the dimensions of a great gallery, (paragraph 206, *three.)*

211. *The envelope gallery, D E F,* in fig. 59, is intended as a base, from which, to run out the listening galleries, even beyond the foot of the glacis; but in this continued form, the envelope presents its outline or side to almost certain destruction from the enemy's globes of compression: suppose *g g*, fig. 59, to represent the effects of two of the enemy's surcharged mines, that destroy the portions of the envelope at *m*, *m*, within their influence; the part, *s p s*, of the envelope, is no longer of any use to the besieged, there being no communication to it; besides which, should any of the miners have been at work in it, they will be buried alive: the assailant also will clear away the rubbish from the crater of his mines, and penetrate at *s s*, into this ready made gallery; which will be very useful to him. The envelope gallery when made in a continued line, is not so much approved of, as the construction of portions of it, at the extremities of the galleries of communication, from which to push on listeners.

The portions of the envelope should have the dimensions of galleries; (paragraph 206, *three*).

212. *Galleries of communication.* Fig. 60, *b b*, are always formed; whether the envelope be made as a continued gallery, or as portions of galleries: and, that they may answer their name and purpose, they should have the same dimensions as the envelope gallery.

At certain distances, grooves are made in the masonry walls of these galleries, (as *b b*, fig. 60) in order to interrupt the communication by a barrier of beams and sand bags, when the enemy has gained the envelope gallery; and when pressed for time to fire a mine, these little barriers assist in the tamping.

The extremity of each gallery of communication should be furnished with a strong door to enter the envelope; the wall, right and left of this door, should have loop-holes for pistols, looking into the envelope; that, in case of the sudden irruption of the enemy's miners into the envelope, there should be the means of defending the galleries of communication.

213. *Listening galleries* are to enable the defenders to advance under ground, to the foot of the glacis, or even beyond it, in order to discover the enemy's miner at work, which is done by boring a hole in the earth with an auger in the suspected direction, and listening attentively with the ear applied to the

soil; by hanging up a sheet of iron to different parts of the gallery with the ear close to it; or by placing hard peas on a drumhead and watching whether they vibrate: these means will discover an enemy's miner at work in earth of common tenacity at a distance of ninety feet: consequently, listeners should not be farther from each other than one hundred and eighty feet, that an enemy may not be able to run a gallery between them without being heard: but this is not the only consideration that regulates the distance at which the listeners should be from each other; for these galleries, besides giving notice of an enemy's approach, are intended to be useful in the active subterranean defence, by forming mines, either in them, or in branches run out from them. For example, let the two consecutive listeners, in fig. 61, have a line of least resistance of eighteen feet, then, if they be thirty-six feet apart, they will raise all the space contained between them, as shown in the figure, where the two circles represent the mouths of the craters: but it is to be remembered that the compressing effect of such ordinary mines, extends laterally to more than once and a half the length of the line of least resistance, (paragraph 206, *eight*); therefore, if the listeners be about fifty-four feet apart, with a line of least resistance of eighteen feet, an ordinary mine, in each, will destroy any gallery an enemy might attempt to drive between them: and should the charges have chambers formed for them in returns, as recommended, (in paragraph 206, *four*,) and as seen at *r r*, fig. 62. it will allow the listeners to be still more asunder, depending upon the length of these branches or returns *r r*, at the extremity of which the charges are lodged: consequently, the distance between the listeners depends, not only on the nature of the soil that conveys the sound, but likewise on the depth that the charges are lodged below the surface of the ground.

Listeners cannot be very long without being uninhabitable; as experience has shown that they are unfit for respiration when more than one hundred and fifty feet long.

As listeners offer their points or ends to the approach of an enemy, they are most favourably situated for avoiding the destructive effects of his globes of compression. Whenever the defender ascertains that the assailant is preparing a globe at a distance, it is recommended not to use the most advanced mines in a fruitless endeavour to crush him, but to make cuts or galleries across them, (as *o o* fig. 59), with a view of lessening the effects of the globes, part of the force of which may lose itself in these recesses, and thus to seek to parry the first blow: but as soon as the globe has been fired; when the full extent of the evil has been ascertained; and the exact route of the enemy's miner discovered, by his vast crater, the offensive is taken immediately, by forming mines at the points of the listeners nearest to him; or by running out branches so as to crush his new galleries or retard his progress.

If listeners be made of the dimensions of small galleries, (paragraph 206, *three*) they will answer all the purposes just detailed, and they can then be tamped more quickly, than if made larger. It is customary to leave unfinished oblong or arched spaces in the masonry piers of these galleries, where branches are likely to be run out; and also grooves in the masonry, from space to space, to aid in the tamping: in fact, the engineer charged with the construction of defensive mines should do his utmost to profit by his galleries, so as always to have less length of branch and less work to perform than the besieger; and to be beforehand with him after the discharge of his first globe of compression.

214. Thus the defenders secure to themselves the means of forming mines wherever circumstances may render them necessary: but in their arrangement, it is necessary to be careful that the innermost mines do not, by their explosion, entail the ruin of the crest of the glacis, and leave the covered way and part of the scarp revêtement exposed. Whatever may be the depth of the defensive mines, they should be arranged on the principle

seen in fig. 63: where they are on an inclined plane *C C* nearly parallel to the slope of the glacis: here, the depth of the mines is supposed to be eighteen feet; a distance of twenty-five feet is set off from the crest of the glacis, and the line *A B* which is to pass through the focus of the last mine, forms an angle of 45° with the slope of the glacis, so that after its explosion, there will be a sufficient thickness of parapet *d e f* to screen the covered way. These last mines are intended to destroy the enemy's breaching batteries which must be established on the crest of the glacis, should he be so imprudent as to construct them before securing himself underground. Mines are seldom made under the terre-pleine of the covered way, as it is inconvenient for an enemy to lodge himself upon it; and the craters of such mines would, by the destruction of the counterscarp revêtement, aid the enemy in descending into the ditch.

215. In fig. 63, the most advanced listener *l* is fifteen feet below the level of the ground; and the counterscarp gallery *m* is twenty-two feet below the same line; the general slope of the galleries on the inclined plane *l m* is seven feet; which has the advantage of keeping them well drained; (the shaded part in this figure, represents the masonry of the arches); *i i*, are unfinished portions of masonry, left so in the first construction, from which to run out the ascending branches *ik*, *ik* at the moment of need, to establish the mines *k k* at the required spots and in the line of the plane *C C*.

216. Where galleries cross each other, as at *c* fig. 60, enlargements are made which are higher than the galleries, and well arched; and sometimes aired by a funnel (as shown at *h* fig. 62): these spaces are very useful to enable the workmen to cross each other with ease; for the depositing of earth from the wheelbarrows, to fill the sand bags for tamping; for depôts of tools, &c.; and they should be made in long galleries that may not be crossed by others, to answer the same purpose. Likewise, in the general arrangement of the defensive mines, every attention should be paid to the obtaining of currents of air.

217. In applying the foregoing principles to a system of defensive mines on a front of fortification traced according to the modern system, as in fig. 64; it is to be observed, that the dimensions and saliency of the ravelins is supposed to be so great, as to throw the ground *(Æ)* before the bastions, into contracted and re-entering spaces between them: it would therefore be needless to multiply costly galleries before the bastions, where the enemy does not attempt to establish himself till the besieged are driven from the outworks, and confined to the enceinte, so as to be unable to communicate with the counterscarp gallery without great risks, (unless there be a gallery of communication underneath the ditch, which is a rare construction.) The chief subterranean defence is therefore shown here before the ravelins. The tracing of the galleries in fig. 64, is as simple as possible, combining the leading features of the system of *Lebrun* and General *Marescot*: the dotted line $x y z$ indicates the first line of mines made on the principle shown in fig. 63 under the letter x; the dotted line $p q r$ in fig. 64, shows the last lines of mines agreeing with those made under p in fig. 63. At thirty-nine yards parallel to the line $q r$, $A B$ is traced; and at the same distance still further in, the line $C D$: both these are portions of transverse envelope galleries; they afford a good circulation of air to the listeners in connection with them; and are too short to be much exposed to the evils mentioned in paragraph 211. A reference to the plan, fig. 64, will explain the remainder of the tracing: twenty-two yards are laid off on each side of the capital C and D; which are joined to the points q and r, by lines showing the two great listeners $C q$ and $D r$: these together with the great listener on the capital, answer also as galleries of communication: between them, are two other listeners, proceeding from the envelope $A B$ and occupying the space betweeen q and r on the principle laid down in paragraph 213; that is, the listeners from q to r are about fifty-four feet apart, in the most salient part of the tracé, which will be first menaced, and where mines can be most promptly made to arrest the advance of the besiegers.

The lateral dispositions are still more simple: on the line *qp*, distances *qE*, *EF*, &c. are laid off, each equal to twenty-eight yards; *E* is joined to *C* and parallels are drawn to *EC*, from each of these divisions; which give the lateral listeners; these distances will enable the besieged miners to get at their enemy by running out branches of only sixteen or eighteen feet in length, should he attempt to push between them: to make these galleries habitable at their extremities, they are crossed by others as *KI* proceeding from the gallery of the counterscarp to midway between the crest of the glacis and the line *pq*: these likewise answer for communications and listeners; from which branches can be run out where needed: this keeps the most advanced part of the listeners within thirty-eight yards of the circular aired recesses *I*, and admits of sufficient ventilation.

218. Under the salient of the ravelin, mines are prepared as seen in fig. 64, to blow up the assailant's lodgment on the breach; the galleries that lead to these mines have their openings into the ditch of the redoubt of the ravelin. Should the ditch be dry, branches and mines can be prepared under the level of the ditch, (as seen by the dotted lines *f* in fig. 64, and *aa* in fig. 65), to blow away the rubbish of the breach, before, or at the moment of assault: in this case, galleries can likewise be made to communicate from the ditch of the redoubt of the ravelin to the counterscarp gallery, as *gg*, fig. 64.

219. As to the defensive mines in the bastions, the usual arrangement is that shown in fig. 64. The escarp gallery *MN* is at about sixty feet in rear of, and parallel to, the revêtement of the faces of the bastion: it serves as a base, from which to run out branches, and to form mines, *aa*, *bb*, figs. 64 and 65; the first under the rubbish of the breach; the second under the lodgment made by the enemy near the summit of the breach. If the ground be so dry as to admit of a gallery being constructed on the capital of the bastion under the ditch, it will be useful to run galleries *h*, and prepare chambers *ll*, fig. 64, to overthrow

the counterbatteries of the besiegers, should he endeavour to establish them in the usual place, without having previously shaken the ground by his globes of compression.

Empty bastions are more suited for defensive mines than full bastions, since the escarp gallery can then be made at the interior slope of the rampart, where it can be well aired and lighted.

220. *On the attack of the foregoing system of mines.* The great listeners are generally pushed to about the foot of the glacis, where the enemy establishes his last parallel of attack; but if he should be aware of the existence of the defensive mines, he will form this parallel *P P*, fig. 64, at one hundred and fifty feet, or more, beyond the foot of the glacis; and will direct branches upon the points *q* and *r*, till he arrives within about ninety feet of them: he there gives his chambers a depth of twenty-two or twenty-three feet, and charges them with three or four thousand pounds of powder; and, by their explosion, he ruins the extremities of the first listeners: for the effect of such a surcharged mine will extend horizontally to four times the length of the line of least resistance. From these vast craters, he advances simultaneously on every side, in order to prepare for similar explosions; and, by the fourth explosion, he will probably succeed in annulling all subterranean defence, and blowing in the counterscarp; as is indicated by the great dotted circles, in fig. 64, between the parallel *P* and the counterscarp of the place.

221. Although globes of compression thus place great power in the hands of the assailant, it is to be remembered that expert and bold miners cannot proceed in their arduous work of driving galleries at a greater rate than from fourteen to eighteen feet in twenty-four hours;* consequently, a considerable delay

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* At Burgos, Sir John Jones says, the inexperienced miners there were one hundred and eight hours piercing through sixty feet; practised "miners would have done it in seventy-two hours," which would give twenty feet in twenty-four hours: but at page 314 of the first volume of his Sieges, detailing this operation, he says, the gallery was three feet

is experienced by the assailant in pushing on his attack above ground; for example, take the four galleries between *P* and *K*, in fig. 64, for the globes of compression, and they measure together three hundred and sixty feet; which, working at the rate of twenty feet in twenty-four hours, will occupy a period of eighteen days, (exclusive of the time taken in preparing the chambers, tamping, &c.): and there is no manner of abridging this work, as it is impossible for more than one man, or, at most, two men, to excavate at the head of a gallery at the same moment. The assailant then advances as rapidly as one active expert man can remove away the soil before him in a small gallery.

Meantime the besieger proceeds with his trenches and attack above ground, in proportion as he secures himself below; and, if six days be allowed as a fair time to work up from the foot to the crest of the glacis, in the attack of fronts without countermines, here it is calculated to occupy a period of eighteen days with good countermines; thus adding at least twelve days to the duration of the siege, supposing the attacking party to possess great means, skill, and conduct; and, without a full combination of these, the delay is incalculable, and may save the place.

222. The defensive galleries hitherto spoken of are supposed to have been constructed of masonry, either at the original building of the fortress, or afterwards, with every advantage of

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wide by four feet high, "*the soil stiff and standing well without support.*" Therefore, when we say that expert miners cannot proceed more quickly than fourteen or eighteen feet in twenty-four hours, we mean in soil requiring to be supported at the top and sides by timber frames and planks. At the siege of St. Sebastian in 1813, Sir John Jones details some of the mining operations thus;—"The soil being a loose sand, the whole of the interior was obliged to be sustained by framework; the frames were placed two feet asunder. Three days were passed before the miners (uninstructed men procured from regiments of the line) could acquire any degree of expertness in driving the gallery; but after that period they penetrated and completed sixteen feet in twenty-four hours with ease, even when the gallery had extended to a length of eighty feet."

time and means; but *Mowzé* (an intelligent French engineer, who has written ably on the subject) is of opinion that, if a garrison be furnished with two hundred and fifty good miners, provided with plenty of tools and timber, a system of counter-mines may be constructed, or a front in thirty days, as efficient as those of masonry, which cost twice as much, and occupy a period of five months in building and completing.

223. It remains to say a few words on the usual mode of sinking shafts and driving galleries. The miners are furnished with plenty of light tools, such as pickaxes, shovels, rakes, having shifting handles to permit their being used in the smallest spaces; also light wheelbarrows, or small waggons on trucks, to remove the soil from the head of the gallery to the foot of the shaft; and baskets to hand up the soil by a small windlass from the bottom to the top of the shaft. The gallery frames and sheeting are previously prepared.

224. *To sink a shaft.* The shaft frame, as seen in fig. 66, is made of strong scantling of timber, of about four and a half by three inches, having projecting ends, *a b*, *c d*: this frame is laid flat on the ground, which is previously grooved, so as to admit of the frame being flush with the surface of the ground: the size of the frame depends on the dimensions of the shaft; the directions *b d*, *b d* are to be exactly in the line of the intended gallery: the ground is then excavated for the depth of four feet, not only within the frame, but for a small space all round without the frame, to admit of the sheeting or side planks being pushed down, as seen in fig. 68: the shaded part in fig. 66 shows the extent of the excavation. When the miners reach a depth of four feet, a second frame, without projecting ends, is laid quite level, and connected to the upper frame by strong ropes that pass through the eyes made for them in the frames, and fastened by wooden pins, as seen in fig. 67, *e f*: the side sheeting or lining is then pushed down between the frames and the earth, to support the sides of the pit and to prevent the soil falling in: in earth of common tenacity, two planks will generally suffice for each side

of the shaft, as seen in fig. 68 : these planks, it is to be observed, are formed with an edge end, to make it more easy to push them down. During the work, the miners make the excavation a little greater all round than the dimensions of the frame, in order to admit of the sheeting fitting in properly; to facilitate which, wedges *c c c c*, fig. 68, are used, to keep out the bottom of the sheeting already fixed, in order that the new set of planks to be introduced, may have sufficient space. Thus the sinking of the shaft is continued to the required depth at which the gallery is to be driven: let fig. 69 represent the bottom of the shaft; here care is taken that the depth *d f* is amply sufficient for the height of the gallery frame *e e;* and, in finishing it, the earth on the side of the shaft from which the gallery is to be driven is left bare without side sheeting.

225. *To drive a gallery.* Fig. 69 shows the beginning of the gallery, and its first frame in elevation: fig 70 shows the first and second frames in section, the stanchions being sunk into holes *h h* to steady them: while the excavation is proceeding, the capsill *g g*, fig. 70, is kept in its place by wedges, and when the miner advances four feet he fixes a second frame, the wedges are taken out, and the top sheeting is pushed in over the first frame, to rest upon the second frame: immediately over the capsill of the latter, wedges are again driven in, to lift up the edge end of the first sheeting, and prepare room for the insertion of the second set of top sheeting planks. But if the soil be so loose as not to adhere together at top for a space of four feet, while the miner works from one frame to another, it is customary to push the top sheeting on by degrees as the excavation proceeds, supporting it by temporary stanchions, which are removed when the regular frames are placed.

226. Ascending and descending galleries, as seen in fig. 71, are made in like manner: *A*, the shaft; *B*, the ascending gallery; *C*, the descending gallery. Some engineers advocate the mode of placing the frames in such galleries, perpendicular to the general slope of the gallery, as at *C;* but the more approved plan seems to be, to place them vertically, as at *B.*

227. In proportion as the soil becomes loose or sandy the difficulty and delay of working in it increases; as in bad soil, complete rectangular frames become necessary, having groundsills as well as capsills to prevent the stanchions sinking: in such a case, too, the top must be perfectly sheeted with planks, and the sides of the gallery also; so that the execution of galleries becomes tedious and difficult*.

228. In subterranean warfare the defensive miners have advantages in proportion to the badness of the soil, as their galleries are all previously prepared, and they have only short branches to run out wherever required: but the assailant has all his laborious work to perform.

229. Chalk is the best soil for mining; as the slow and troublesome process of supporting the gallery with frames and sheeting can be dispensed with. Elliptical shafts and arched galleries will stand in chalk without support.

In order to complete this subject in as far as the limits of this treatise will permit, the compiler introduces the following extracts, from his "*Popular View of Fortification and Gunnery*, published in the United Service Journal, in the years 1830 and 1831.

230. The mining operations at the siege of *Schweidnitz*, in 1762, afford a good instance of the defensive properties of

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* At page 61, vol. ii. of his Sieges, Sir John Jones says, "Two shafts on the right of the isthmus, (of St. Sebastian) commenced on the 24th, were sunk nine feet, and a commencement made for the galleries of about three feet. The soil was loose sand, and the principal labour consisted in applying the framework, and conveying the sand to the surface.

"It was found necessary, on commencing a gallery, to cut a notch on both sides of the excavation, into which the ends of a strong plank were inserted, and propped up with supporters, after which the sand was excavated from under the plank, and the regular frames applied; this was repeated on each advance, taking care to support the roof and sides previously to removing any great body of sand, as it only held together whilst moist. When, through inattention, this precaution of supporting the sand inch by inch on every advance was neglected, it invariably crumbled down and caused a great labour and delay to clear the gallery.

countermines, when combined with judicious sallies. This place was besieged by the Prussians, and defended by the Austrians for sixty-three days, of which, forty-nine days were occupied in a subterranean war.

The Prussians suspended their trenches of attack above ground at one hundred and fifty feet from the glacis, here a shaft was sunk 16 feet deep, and a gallery driven in advance ninety-six feet, where a chamber was formed to contain five thousand pounds of powder on the 1st of September, which (having a line of least resistance of sixteen feet) produced a crater of ninety-feet diameter, reaching to within sixty feet of the crest of the glacis: this funnel was crowned or taken possession of on the 2nd; from which the Prussian miners commenced a gallery, but were obliged to abandon it on the 6th of September, in consequence of coming to water, though they had driven it twenty-two feet, and were twenty-one feet below the surface of the ground; another gallery was then made on the left of this and nine feet higher, and carried forward sixty-eight feet by the night of the 10th of September, when the miners of the defenders fired a fougass, which overthrew and damaged twenty-four feet of this gallery near its centre. The Prussians re-established and lengthened it to seventy-two feet when they reached a gallery of the place, from which they drove the miners of the besieged by a fire of musketry. However, the defenders immediately afterwards exploded a mine close to this gallery, which destroyed sixty feet of it, thus leaving merely twelve feet uninjured.

Next day the Prussians began another gallery on one side of the last, the repair of which they also undertook, which led them, on the 12th of September, into the funnel of the defenders' mine that had destroyed their gallery, where they lodged themselves. Meantime, the new gallery being driven forty-two feet in advance, notwithstanding the interruption of two explosions from the defenders, the Prussian miners met a ruined gallery of the besieged twelve feet under ground, where they lodged a charge of two thousand pounds of powder, tamped their branch for thirty-six feet, and fired this mine on the morning of the 16th, which produced a crater of sixty-feet in diameter, reaching within twelve feet of the crest of the glacis; (but this explosion ruined both the crowning of the old funnel and the branch leading to it, which were not again used:) a traverse was now made in the new funnel as a shelter for the party protecting the miners, who immediately began a branch, but which was overturned on the 17th by a fougass when only eight feet in length. Four branches from the same funnel were in like manner destroyed by the defenders' fougasses between the 17th and 20th of September.

The Prussians, finding so much difficulty, determined to occupy the attention of the besieged by fougasses on one side, while they opened a deep gallery on the other to destroy the counterscarp gallery of the place by a globe of compression. On the 24th, the king (Frederick the Great) went to see this gallery when only twenty feet in length, and ordered a return of four feet and a chamber to be made, in which three thousand pounds of powder were lodged in sand bags, and the gallery hastily tamped: this mine had a line of least resistance of twenty feet, and by its explosion gave a funnel of sixty feet in diameter, reaching within eight feet of the crest of the glacis. In this funnel, two traverses were made to screen the party who protected the miners, who opened two branches from it on the 25th, and drove one fifteen feet, and the other eleven feet, in advance, by the 26th; the defenders destroyed the latter by a fougass, and greatly injured the other: they also sallied boldly that night, possessed themselves of the funnels, and so sloped away the glacis to the bottoms of the funnels as to prevent the enemy re-establishing himself there. They retired at daylight. At length, after various struggles of a like kind, a gallery ninety-six feet long was completed by the assailants; its chamber was charged with five thousand pounds of powder; it was tamped for forty-five feet, and fired at midnight on the 8th of October; the explosion destroyed the covered-way, and filled the narrow ditch within it with rubbish; which, together with the misfortune of a casemate filled with powder blowing up in the gorge of the attacked work, and the place being destitute of ammunition and provisions, caused its surrender on the 9th of October.

This was the first siege in which the surcharged mines or globes of compression were used; the attack was conducted by Major Le Febvre, of the Prussian engineers, and from the foregoing account, it is seen that four such mines were employed, viz:—

Charge.—lb.	Depth of the Funnel in Feet	Diameter of the Crater in Feet.
1st. 5000	17	80
2nd. 2400	15	60
3d. 3600	16	60
4th. 5000	16	

The effect of this last mine was very great, throwing in the covered-way and the counterscarp.

But as the lengths of all the lines of least resistance, as well as the nature of the soil at Schweidnitz, have not been recorded, the satisfactory conclusions that might otherwise be drawn from these operations, are wanting.*

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* From this relation of the siege of Schweidnitz, and from many such defences, a high opinion might be formed on the strength of this place and of fortresses in general; but the garrison who thus defended themselves for upwards of two months, consisted of eleven thousand men, commanded by General Guasco, under whom the celebrated Gribeauvel directed the artillery and the defence. After a feeble and unsuccessful effort made by Marshal Daun to relieve the place, it was obliged to surrender, with its garrison reduced to eight thousand six hundred men; yet it had not been breached, nor was it near being so; the covered-way was not in possession of the Prussians, nor the ditch passed; but a chance grenade blew up the principal powder magazine on the 8th of October. The loss of the Prussians was three thousand two hundred and twenty-eight men killed and wounded; that of the Austrians two

The same officer, Le Febvre, details an experiment made by himself in sandy soil near Potsdam. He charged a mine, whose line of least resistance was fifteen feet, with three thousand three hundred pounds of powder. Three galleries had been prepared on nearly the same level as the mine, at the respective distances of twenty-four, thirty-two, and forty-two feet from the chamber; and a fourth gallery at sixteen feet below the chamber. All these galleries were of oak timber, five feet high by three feet wide. After the explosion, the diameter of the funnel measured sixty-six feet, its depth eighteen feet, and the greatest part of each gallery was destroyed.

The general rule given by Belidor for finding the charge of a surcharged mine or globe of compression, is to multiply the length of the line of least resistance in feet by three hundred, and the product will be the weight of the powder in pounds: thus the line of least resistance being fifteen feet, multiply it by three hundred, and the result is four thousand five hundred pounds, which gives a much larger charge than Le Febvre used at Potsdam in the sandy soil.

231. This leads to the consideration of the quantity of powder required to produce certain effects. Questions have arisen amongst the masters of the art as to the description of curve which the crater or funnel will assume by the explosion of powder in a mine. Vauban and Belidor considered the

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thousand eight hundred. A very different opinion of this srong hold might be formed, when it is related, that in 1758, "the Austrians evacuating Silesia after the battle of Leuthen, kept possession of Schweidnitz, which was placed in the best state of defence, and garrisoned by eight thousand men, under General Thierheim; yet the Prussians carried it by escalade in less than half an hour, on the night of the 15th of April." (See *Jomini's Traité des Grandes Opérations Militaires, chap.* x. *vol.* 2). We see how much depends on how, and by whom, a place is defended.

Vauban, who so well knew the qualities necessary to command a fortress, said, "That out of the multitude of gallant and distinguished generals in the French army in his day, he did not know six who were fully qualified for so important a trust.

funnel to have the shape of an inverted cone: while De Valiere thought it had the properties of a parabolic curve: these opinions, however, have not interfered with an endeavour to determine experimentally the proper charges for soils of different tenacities. It can be shown by an easy calculation,* that the solid mass raised by the effect of a mine is equal to the cube of the line of least resistance, multiplied by $\frac{11}{6}$. Now the following table shows the quantity of powder necessary to raise different kinds of earth, masonry, and rock, established from experiment by Mouzé.

	To raise one cubic foot.		To raise six cubic feet.		
	oz.	drs.	lbs.	oz.	drs.
Common earth mixed with sand	0	11·62	9	12	13·92
Strong sand, or sandy stone .	0	15·47	13	0	13·52
Potter's clay.	1	0·64	14	0	10·24
Loose and moveable sand. .	1	1·56	14	13	0.96
Old masonry.	1	2.4	15	8	6·4
Freestone, or rock	1	4·33	17	2	7·28

To use this table, suppose it should be required to ascertain the charge of a mine necessary for a two-lined crater, having its line of least resistance equal to ten feet, in a soil of potter's clay; first, cube the line of least resistance, ($10^3=1000$). Then the solid content of the excavation being equal to $\frac{11}{6}$ of the cube of least resistance; multiply $1000\times\frac{11}{6}$ which will give 1833·326 cubit feet: again, multiply this last result by the number of drams opposite potter's clay in the table, that is, by 16·64 drams, (which is the same as 1 oz. 0·64 drs.) and the produce is 30506,54464 drams, or 119lbs. 2 oz. 10 drams.

The rule therefore is, *multiply the content of the excavation in feet, by the weight of powder corresponding to the soil in the table, and the product will be the charge.*

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* Landmann's Treatise on Mines, p. 81.

Vauban calculated that for a mine necessary to blow up (one cubic toise or) six cubic feet, it required, if

	lbs. of powder
Light earth mixed with sand	11
Common earth	12
Loam or strong sand	15
Clay or fuller's earth	16
Old and good masonry	18
Rock	20

Vauban formed this table from a great number of experiments, the results of which, coming from a man of all others most capable of making them, may be adopted with safety and confidence.

The following rule is given in the "Manuel Pratique du Mineur ; Par le Capitaine du génie Villeneuve, imprimé à Paris, (1826,) par ordre de S. Ex. le Ministre de la Guerre.

"To find the charge of an ordinary mine, established under ordinary earth, such as requires twelve pounds per cubic toise (six cubic feet) to raise; express the line of least resistance in feet; cube it; and in the result, suppress the last figure on the right, then there will be to the left the number of pounds of powder required."

Suppose ten feet to be the line of least resistance, its cube is one thousand; suppress the last figure 0, and there remains one hundred pounds of powder, which is nineteen pounds less than Mouzé's tables would produce, as has just been shown above.

The size of the chamber depends on the quantity of powder to be lodged in it. Le Febvre and Mouzé are of opinion, that a small space being left round the powder will produce a greater effect than when the chamber is made exactly to contain the box with the charge; but what this vacancy ought to be has not yet been determined; indeed, subsequent experiments have thrown some doubts on its efficacy.

A pound of gunpowder occupies thirty cubic inches, from which the dimensions of any cubical box to contain a given quantity can be calculated, simply by multiplying the number of pounds by thirty, and extracting the cube root of the product: for instance, let it be supposed that the charge to be used is two thousand pounds of powder; then

$$2000 \times 30 = \sqrt[3]{60{,}000} = \text{a little more than } 39.$$

Now a box of this size, three feet three inches and a quarter, would be inconvenient, and could not even be got into a small branch: four smaller boxes should therefore be provided, so as to hold the required quantity, and to form the cube in the chamber. But if the mine is to be fired as soon as loaded and tamped, the chamber may be lined with planks or straw, and the charge put in bags.

232. The expression of the "miner being attached to the wall," is often met with in the records of sieges, which needs some little explanation to such of our young military readers as may not be acquainted with it.

Let it be supposed that it is required to make a breach in the flanked angle of the work, *R*, fig. 72; that the assailant is in possession of the counterscarp and that the flanking fire of artillery defending the ditch of the work has been silenced. A parapet is made across the ditch, as *P P*, fig. 72, which is increased in height at the escarp. Here the miners place strong beams against the revêtement as seen at *S* in figs. 72 and 73, over which planks are laid, covered with sand-bags and green hides of animals to form a strong roof, to shelter themselves from shells, grenades, and combustibles, that the defenders might roll down from the parapet above. Under this cover the miners proceed to enter the wall, and this is what is called attaching the miner to the wall.[*]

Four chambers, *C*, *D*, *E*, *F*, figs. 72 and 73, are formed in a line with the tail of the counterforts, the distance from chamber to chamber being about thirty feet. If possible, chambers, *G*, *H*, are advanced into the rampart, so as to render the slope of the breach, *L O*, fig. 73, made by the explosion of the mines, as easy as possible for the assault. This work will occupy four days at least; therefore, it is not so expeditious a mode of forming a breach as that of establishing breaching batteries, *I, I, I*, fig. 72 on the counterscarp, which would batter down the scarp revêtement and make a breach fit to assault in a few hours.

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[*] A very recent instance of the effects of attaching the miner to the wall, has been seen at the siege of Antwerp, in the unflanked ditch of the lunette St. Laurent.

233. Hitherto mining has been described as far as it could be effected by the pick and shovel, but when harder substances are to be encountered than common earth, these are no longer of any avail: it is true, that in quarrying in sandstone, which consists of regular layers, the pick, the wedge, the hammer, &c. suffice; but to make way through rock, good masonry, and hard clay, a more powerful agent is necessary,—and gunpowder is used to effect it by *blasting* away the part required.

The instruments used in blasting are very few and simple; the borer or jumper is a cylindrical piece of iron, that varies in its length, thickness, and weight, according to the work to be done; it has its end either pointed or formed into three edges, to suit the hardness of the rock to be bored. When the hole to be bored is small and not deep, a single man performs the work; he drills a cylindrical hole, by holding the borer in his left hand, and, as he keeps turning it continually, he strikes it with a hammer of about eight pounds weight, which he wields with his other hand.

When the hole to be bored exceeds a foot in depth, and an inch and a half in diameter, one man, sitting down, holds the jumper, while another strikes its head with a hammer of ten or twelve pounds weight; the man who holds the jumper keeps turning it between every blow, feeds the hole with a little water, and cleans it out with an iron scraper, as it is perforated. Should the hole required be more than two and a half feet deep, the jumper must be about eight feet long, pointed at each end, and having a swell in the middle to add to its weight, and make it more convenient to grasp. The hole is begun as usual with the borer and hammer, and, when some inches deep, the jumper is used; one, two, or three men hold it in a standing position, and allow it to fall by its own weight into the hole; raise it out and let it fall again; these repeated blows of a long heavy jumper, effect the required purpose rapidly: the hole is then carefully cleaned out, and is ready to receive the required charge of powder. The boring can easily be carried on in hard limestone at the rate of two feet per hour, with the jumper of large dimensions; but with the small borer and hammer, at the rate of only one foot per hour.

The dimensions of holes vary according to the purpose required, from half an inch to two and a half inches in diameter, and from six inches to many feet in depth. Of course, care must be taken that the line of least resistance is not in the direction of the hole; that is, if a hole should be perforated parallel to the side of a rock for a depth of thirty-six inches, the distance of the hole from the side of the rock should not exceed twenty-eight or thirty inches.

It is difficult to say what the charge of powder ought to be; there has never been any very precise rule given; the experience of the miner, and the tenacity of the rock or masonry to be removed, being the chief guides. We shall soon give some examples of this kind of work, to serve as some little clue to the proper charges to be used. That (the charge) must be arranged before the bore is made; then, the mode of proceeding is to fill it about half full with gunpowder; to tamp and to prime it before it is fired; for which, an iron pricker, tipped with brass, is inserted, and kept close to the side of the hole, the brass end touching the powder; (this is withdrawn afterwards to admit the priming powder). While the pricker remains, the tamping is performed by ramming burnt clay, pieces of pounded brick, stone, and rubbish, with a bar of iron, which is nearly large enough to fill the hole, but having a groove in it to prevent the pricker being disturbed; the hole is thus filled, taking care to turn the pricker often, as the tamping goes on. There is much danger in this operation, especially where the pricker is altogether of iron, for a spark of fire arising from a collision of these substances, most likely to produce it, has often caused serious accidents. The wadding first laid over the powder, is gently and carefully forced down, but as the hole is more filled up, the miner rams the tamping stronger and harder till the hole be filled; the pricker is then withdrawn, and the small tubular space which it occupied, is filled with the priming powder: a piece of portfire, or slow burning match, is secured to the top of the priming by clay, which, being lighted, gives the miner time to retire out of danger.

We understand that tamping with sand is much practised in the quarrying in Scotland: and as tamping in the manner already described is a perilous operation, it is very desirable to use sand if it be as effectual; for not only will it ensure safety, simply to pour in sand over the powder till the hole be full, but it saves all the time that would be occupied by the common mode of tamping. In the "Encyclopædia Britannica," in treating of this subject, it is said—

"The writer of this article has also had considerable opportunities of trying the accuracy of these statements, *as to the efficiency of sand*, at the extensive quarrying operations which lately became necessary in cutting down a part of the Calton-hill, in forming the new approach to the city of Edinburgh, where upwards of 100,000 cubic yards of rocky matters were removed, and gunpowder to the value of nearly 1000*l.* sterling was expended, chiefly in blasting rock, consisting of whinstone, or greenstone, much traversed by calcareous spar. The holes in this work were bored of various dimensions, both as to calibre and depth, and also at all angles of inclination, from the perpendicular to the horizontal. Trials were here made with holes, from three to seven or eight feet in depth, and of a diameter from one inch to two and a half inches, when it was invariably found, that when the powder was wadded with sand, the effect in tearing or blasting the rock was as great as when the more commonly followed method of ramming with pounded stone was adopted."

In priming holes tamped with sand, a clean dry wheaten straw, filled with powder, is put in before the sand is poured upon the charge: and if the hole should slope so much as to have a greater angle than 45° with the horizon, by which the straw would be pressed upon and injured, a small cylindrical tube of sheet-copper must be provided to enclose it.

In the article just quoted, is the following remark on blasting under water:—

" Blasting with gunpowder under water, is necessarily performed in various operations of the engineer, particularly in the excavation of the foundations of piers, and in deepening the entrances of harbours. This is performed by inserting the charge of powder into the perforated rock, by means of a case or cartridge made of tin-plate. The lower part is made to fit the bore in the rock as nearly as may be ; from this a small pipe of the same metal is carried to the surface of the water, with the priming powder. Here wadding is unnecessary, the pressure of the water upon the tin-case superseding the necessity of any ; and the explosive effects are generally greater, in proportion to the charge, than those in the open air. It may here be observed, that explosions under water have, in some instances, been proposed as a mode of attack in marine warfare ; and it is presumed that explosions at considerable depths might occasion such an impression on the water, and so disturb the equilibrium of the atmospheric pressure, as to be capable of sinking large ships or floating batteries."

That which has been done to benefit commerce in canal, road making, coal mining, &c., could never have been effected so extensively without the powerful agency of the explosive force of gunpowder. In France, a tunnel of about seven miles in length, has been lately made; and in England, on the canal joining the rivers Severn and Thames, at Marsden-hill, there is a tunnel upwards of three miles in length, both of which have been forced entirely through rock by the use of gunpowder.

To illustrate this subject still farther, the diagram fig. 74, is added, from an actual experiment, detailed in Landmann's Treatise on Mines: the tube *e l* being an enlarged view of *a b*.

a b, Hole bored in the rock of two inches and a half in diameter, and about two feet six inches deep.

e l, The charge, consisting of fourteen ounces of powder, into which was inserted the quickmatch *d e*, when the hole was filled up with very dry sand.

f, A priming of loose powder on the top of the quickmatch.

g h, Portfire to communicate with the priming.

i k g, Some loose sand or earth thrown upon the priming to prevent accidents from sparks, while the man lights the portfire.

m, *n*, *o*, *p*, Represents the section of the excavation.

The sand here answered the purpose most fully. The immense galleries excavated at Gibraltar, commanding the Neutral Ground, could alone have been executed by such an agent as gunpowder.

The formidable escarpments that render the greatest part of Fort Regent at Jersey inaccessible, have been made by thus blasting the granite rock on which the fort is situated.

At Gibraltar, where blasting is executed on a very great scale, and where the jumpers are of large dimensions, a bore, about twelve feet deep, is loaded at first with four or five pounds of powder (the line of least resistance being considerable, even ten or twelve feet); this first charge explodes without tearing off any part of the rock, and even sometimes without blowing out the tamping; but it rends the bottom of the hole into crevices; a second charge is then poured through the pricker hole, which being exploded, produces greater effects, and more considerable fractures below; another charge is poured in till all the vacant places are filled; and so on, till the rock is torn asunder; hence, immense charges are sometimes used, and it is understood that even a barrel of gunpowder has been expended in the last charge.

234. The following are the usual modes that have been followed to destroy *bridges, revêtements, and buildings*, by mining or blasting; the pick, shovel, lever, and pincher, being used when it is practicable, but in matter too hard for them, the borer, jumper, and blasting, must be substituted.

Destruction of the bridge of Huy, in the Bishopric of Liege, during the campaigns of Louis XIV.

"This bridge was of hard stone; the piers were thirty feet long, and twenty-two feet thick above the offsets, and exclusive of the breakwaters at each extremity. (See figs. 75 and 76).

Twelve miners and a sufficient number of labourers were employed fifteen days in preparing four chambers in each pier; the branches *a*, *b*, and *c*, were eleven feet long, and the returns four feet. The two chambers *m* and *n*, were eight feet distant from centre to centre of each other; and those marked *l* and *o*, were four feet from the former. The openings of the branches were made five feet above the surface of the water: the chambers *l* and *o*, were each loaded with five hundred pounds of powder, and those of *m* and *n*, with four hundred pounds: the fire was communicated to the chambers in each pier at the same time; for which purpose a hole, *h*, was made in the middle of the transverse measure of the bridge, and through the keying of the arch, to admit the powder hose, or sausage, that was tied by a strong rope; the ends *r* and *s* being fixed to the central powder house, *i k*, *i k*, which was placed in casing tubes, fastened to the sides of the piers with iron cramps: the result was successful, the fire reaching all the chambers at the same moment; three of the arches, *A*, *B*, and *C*, were instantly destroyed.*

In this operation we find a period of fifteen days expended in preparation for the destruction of the bridge; a length of time rarely at command in operations of this kind. It is impossible for us to give better information on this subject than transcribing the following memorandum of the various modes practised in Spain under the Duke of Wellington.

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* Landmann's Treatise on Mines.

"Memorandum on the Blowing up of Bridges, by Lieutenant-Colonel Burgoyne, of the Corps of Royal Engineers, dated 6th of September, 1814.*

"In the destruction of bridges during the Duke of Wellington's campaigns, various methods were adopted according to the circumstances of the case.

"The bridges in the Peninsula were usually of stone, the arches from twenty to forty feet span semicircular, and of one stone, eighteen inches or two feet in thickness. The loading of the arches was sometimes of solid masonry, but commonly of loose stones or rubbish.

"The object required generally was to destroy one arch, and in order to give the enemy the greatest inconvenience and delay, the largest arch, and where there was deep water, was preferred, excepting when want of time or ammunition made it advisable to select a particular one that might appear weaker than the others.

"The simplest principle of mining a bridge was found to be by lodging the powder on the haunch of the arch, and as near as could be on the centre of the width of the bridge, with the line of least resistance through the arch.

"The best mode of forming the mine, was where the side walls of the bridge above the piers were slightly built and easily got at, and the loading of the arch of loose rubbish; a small gallery was then run in *A*, fig. 77, about five feet from the arch-stone, and when at the centre of the width of the bridge, a return was made to the arch," (shown by the dotted line in the figure,) "and the powder lodged against it. There are not many occasions where this can be done under a very considerable time; but when practicable it has many advantages; the greatest resistance is obtained to the sides and above; the ammunition is less likely to get injured from wet penetrating to it; there is no obstruction to the road over the bridge while preparing, and less danger of accidents after it is loaded. In this case, the powder, saucisson, &c. are applied in the usual manner in mining; and the end to be lighted is kept within the surface of the wall to be sheltered from the weather.

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* Landmann's Treatise on Mines.

"The common and quickest mode of mining a bridge is by sinking down from the road above to the arch, and lodging the powder in one mass on the centre of its width. To do this with good effect, the shaft *CB*, fig. 78, should be sunk where there will be the greatest resistance gained above and to the sides, as at *B*. As the arch gives so much more resistance than the materials with which it is loaded, the distance to the surface, therefore, should be twice, or three, or even four times more, at least in those directions, than in that through the arch, in proportion to the nature of those materials.

"In this way arches have been blown down with forty-five pounds of powder, and after five or six hours' labour.

"The shaft should be sunk on one side of the centre of the width of the bridge, as at *C*, fig. 79, (which is a plan of the bridge seen in section in fig. 80, the dotted lines in fig. 79, representing the spaces occupied by the arches): and a little return made at the bottom to gain that situation for the powder, by which means there will be most resistance above, and a greater width of road left during the operation.

"In loading, the saucisson was brought up the shaft to within about one foot of the surface of the road, and then carried along a gutter or drain to the side of the bridge where it was lighted, whereby the road was entirely cleared, and a premature explosion from accident less likely to occur. The upper surface of the road was drained off as much as possible, to keep the wet from penetrating to the powder.

"When there was no time to sink a shaft as might be wished, as great resistance must be obtained as can be, by sinking as deep to the arch as there is time for, and increasing the effect by a loading of as much stone or other heavy materials, from the parapet walls or elsewhere, as can be applied.

"A bridge across the Carrion at Duenas was required to be mined in great haste, and it was found that the loading of the arches was of solid masonry; an opening was, therefore, made down to the crown of the arch *D*, figs. 80 and 81, (fig. 80 being a plan, and 81 a section of the arch destroyed), about two feet six inches only; two hundred and fifty pounds of powder were lodged in rather a longitudinal direction along the width of the bridge, and a loading *C* applied of heavy stones and rubbish as high above the road of the bridge as could be without preventing carriages from passing: when fired, it made a gap *E E E E* across the bridge of fifteen feet, which is about half its span.

"The French declare that one hundred pounds of powder laid on the crown of an arch, and without loading, would destroy it; but, in a strong built bridge, I should be sorry to apply so small a quantity.

"As on service the time at command for this kind of operation is very uncertain; it is a common and good mode to commence preparing in two places, one on the crown of the arch and the other at the haunch, and then if not allowed time sufficient to complete the latter and better mode, the powder can be applied on the crown of the arch, and exploded with or without a loading of rubbish, according to circumstances; and it is much better to do that, than to lodge the powder in a shaft only partly sunk down to the haunch, although it should be deeper.

"In some cases where the bridge is very wide, and the operation can be carried on with nicety, it may be right to divide the powder into mines *F* and *G*, fig. 82, across its width; but, in a rough operation, I would certainly never divide the powder; for although it was said once that a hole was blown through the centre of a wide arch, and a passage left on each side, (which, however, I do not believe),—if it was so, certainly that same quantity of powder that gave so nice a shock, would not have injured the arch at all if divided.

"I have seen an instance where about half of the width of a bridge *F G H*, fig. 83, was blown down, which probably arose from dividing the powder in this manner.

"There can be no reason whatever for dividing the powder between the different sides of the arch, as *I K*, fig. 84; by doing so, a failure took place on the Coruna retreat; and if it succeeds, there can be little doubt but that one of the mines would have done as well. Wherever the powder is divided, the explosion of the whole should be simultaneous; the arrangements require much precision, and the chances of failure are of course multiplied.

"Where a bridge is narrow, there can be no occason for sinking the shaft down to the arch much deeper than half the width of the bridge, as the want of resistance at the sides will render the additional vertical resistance superfluous. On one occasion a failure occurred from a shaft being sunk down to a pier with the intention of destroying two arches; but which, although great perpendicular resistance was gained, blew out at the sides, and left the two arches perfect.

"When the effect of a mine can be secured to cut through the arch, the greater resistance that can be given, even in that direction, the better, as it will increase the effect over the whole width of the bridge.

"As it generally happens on service, that the mine cannot be laid according to nice calculation, after applying it in the best way that circumstances will allow, the effect must be gained by increasing the quantity of powder. Under the chance of different difficulties that might occur, it was customary, when practicable, to send two, three, and even four barrels of powder, of ninety pounds each, for the destruction of a bridge, although one would usually be sufficient.

"When there was time, these mines were loaded with all the precautions commonly used; viz. the powder in a box, and the saucisson in an auget; and when to lie any time, the box and auget were pitched, and covered with straw, tarpawling, &c.

to preserve the ammunition dry. When pressed for time and without the proper articles, the powder was lodged in the barrels it was brought in, or laid in a tarpawling, or in bags; and the saucisson was laid without an auget, but with care that the stones or rubbish should not choke it. The mine was lighted by a piece of portfire tied into the end of the saucisson.

"Saucisson is so very easily made and carried, and so advantageous, that latterly we never failed having it with us; in our first mines, indeed, for want of it, we cut off the ends of portfires diagonally, and tied them together to pieces of sticks the length necessary for the train; but such a contrivance is very bad, and owing to it, Lieut. Davy was killed on Sir John Moore's retreat; the mine exploding the instant he lighted it, probably from the fire of the composition dropping down to the powder, for which reason the end portfire should be laid horizontally, and a little clay round it will give additional security.

"A small hollow round the powder in a mine will increase its effects.

"To destroy wooden bridges, powder was sometimes used and applied to the most important supports in the arch according to its construction; but as there is no other resistance than the air, the quantity of powder should be large: ninety pounds have blown down a strong wooden arch.

"The common and best mode with a wooden bridge is to lay the planking bare, and to light a large fire upon them which will burn to the water's edge if let alone; but this will not do if the enemy cannot be kept from gaining possession of the bridge, for at least twelve hours after the fire is lighted.

The Imperial Minister of War in France issued a small pamphlet in 1814, containing some simple instructions for the defence and destruction of bridges, the latter portion of which appears to be much inferior to those contained in the foregoing memorandum, by Colonel Burgoyne. It says,

"To destroy a stone bridge, a trench in the form of a cross is made in the crown of the arch, the branches of which are about ten feet long, and these are sunk down to the top of the arch stones; see fig. 85: one hundred and sixty-one pounds of powder (one hundred and fifty French pounds) are placed in each trench for a thickness of arch of three feet; the powder is covered with strong planks, well loaded with rubbish, and fired by a powder hose, which may be made as long as may be necessary."

Again,

"Stone bridges may be destroyed by simply cutting a trench across the crown of the arch about eighteen inches deep, and placing 345 pounds of powder in it. This quantity has destroyed semicircular arches of twenty-five feet span, and four feet thick at the key: see fig. 86.

"Wooden bridges may be destroyed in three different ways; they may be pulled to pieces, they may be burnt, or they may be blown up.

"When there is not time to destroy them, the planks are unspiked, and the timbers so separated, that they may be speedily removed when necessary. The wood should be either hidden or burnt, so that the enemy may not find it to re-establish the bridge. The best method to burn bridges is to tar them, and to cover and surround them with fascines, or tarred brushwood, as represented in figure 87. It will often be enough to burn the bays of the bridge which are nearest to the enemy.

"In order to blow up wooden bridges, two hundred and sixteen pounds of powder may be suspended under the superstructure, and fired as above described."

These examples of the destruction of bridges are concluded by the following interesting narrative of the passage of the Tamega river in Spain, at Amarante, by a detachment of Marshal Soult's army under General Laborde, extracted from the Second Volume of Coloniel Napier's nervous and elegant History of the Peninsular War.

"The bridges of Modin and Cavez above, and that of Canavezas below, Amarante, were destroyed; the Tamega was in full flood, and running in a deep rocky bed; and the bridge in front of the French was mined, barred with three rows of palisades, and commanded by a battery of ten guns. The Portuguese were in position on the heights behind, from whence they could discern all that was passing at the bridge, and could reinforce at will the advanced guard which was posted in the suburb.

"The 20th, the first barricade was reached by the flying sap; but the fire of the Portuguese was so deadly, that Laborde abandoned the attack, and endeavoured to construct a bridge of tressels half a mile below; this failed, and the efforts against the stone bridge were necessarily renewed. The mine on the other side was ingeniously formed; the muzzle of a loaded musket entered the chamber, and a string being tied at one end to the trigger, the other end was brought behind the entrenchments, so that an explosion could be managed with the greatest precision as to time.

"The 27th, the centre barricade was burnt by Capt. Brochard, an engineer officer, who devised a method of forcing the passage, so singularly bold, that all the generals, and especially Gen. Foy, were opposed to it. The plan was, however, transmitted to Oporto; and Soult sent Gen. Hulot, his first aide-de-camp, to report if the project was feasible. Hulot approved of Brochard's proposal, and the latter commenced his operations on the 2nd of May.

"The troops were under arms, and disposed in the most convenient manner, as near the head of the bridge as the necessity of keeping them hidden would permit; and at eight o'clock, all being prepared, and the moon shining bright, twenty men were sent a little below the bridge, and directed to open an oblique fire of musketry against the entrenchments. This being replied to, and the attention of the Portuguese attracted, a sapper, dressed in dark grey, crawled out, and pushed with his head a barrel of powder, which was likewise enveloped in grey cloth to deaden the sound, along that side of the bridge which was darkened by the shadow of the parapet: when he had placed his barrel against the entrenchment covering the Portuguese mine, he retired in the same manner. Two others followed in succession and retired without being discovered; but the fourth, after placing the barrel, rose on his feet and ran back, but was immediately shot at and wounded. The fire of the Portuguese was now directed on the bridge itself; but as the barrels were not discovered, after a time it ceased; and a fifth sapper advancing like the others, attached a sausage seventy yards long to the barrels. About two o'clock in the morning the whole was completed; and as the French kept very quiet, the Portuguese remained tranquil and unsuspicious.

" Brochard had calculated that the effect of four barrels exploding together would destroy the Portuguese entrenchments, and burn the cord attached to their mine. The event proved that he was right; for a thick fog arising about three o'clock, the sausage was fired, and the explosion made a large breach. Brochard, with his sappers, instantly jumped on the bridge, threw water into the mine, cut away all obstacles, and followed by a column of grenadiers, was at the other side before the smoke cleared away. The grenadiers being supported by other troops, not only the suburb, but the camp on the height behind were carried without a check, and the Portuguese dispersing, fled over the mountains.

" The execution of Capt. Brochard's bold, ingenious, and successful operation, cost only seven or eight men killed; while in the former futile attempts above a hundred and eighty men, besides many engineer officers, had fallen. It is, however, a singular fact, that there was a practicable ford near the bridge, unguarded, and apparently unknown to both sides.

While it is impossible not to join in the full meed of praise given to Capt. Brochard, and while it is acknowledged that the contrivance of exploding the Portuguese mine by means of the loaded musket was ingenious; yet, had there been a regularly secured powder hose to communicate from the entrenchment to the mine, the attempt would probably not have been made ; as, had · not Capt. Brochard had unquestionable information of the arrangement made by the Portuguese for exploding their mine, he could not have calculated on *burning* the cord attached to the loaded firelock—for had he merely guessed that the mine would have been fired in the usual manner by means of a powder hose, he would not have attempted to burn that, which would instantly have communicated to the mine and blown up the bridge.

The next subject, is the destruction of revêtements and buildings by the explosive force of gunpowder.

Revêtements are most effectually destroyed by making chambers in rear of the masonry; usually in every counterfort, or in every second counterfort, taking care that the charges shall produce craters that shall cross each other so as to ensure the entire demolition of the masonry. Charges placed behind the revêtements in the intervals between the counterforts, have been known (when the masonry is very good) to blow away the revêtement, as *a a*, in fig. 88, leaving the counterforts standing, so that the earth between every two is held together by these shattered walls: hence the necessity of lodging the charges in the mass of the counterforts, in order to ensure the complete destruction of the walls.

Allusion has already been made to the method of making breaches by means of destroying the revêtement, in running a gallery from the bottom of the ditch through the revêtement, and branching off right and left to form chambers for the charges in counterforts.

But we now refer to the destruction of the revêtements of a place which is in the possession of the party desirous of destroying them; as in the case of being forced to abandon a post which is to be rendered useless to an enemy: and the mode of proceeding is usually to sink shafts in the mass of earth behind the revêtements, and to form chambers at the back of the masonry.

It has been already shown that the masters of the art are at variance respecting the exact charge necessary to destroy masonry walls : but the approximation which has been made from experiment, is a sufficient clue to regulate such charges in most cases, and in addition to what has been already said, the following statements are adduced.

At page 393, vol. i. Jones's Sieges, we read,

" In the year 1810, forts Barbara and Felipe, in front of Gibraltar, were ordered to be blown up under the direction of Capt. Harding. To effect this he sank shafts from the top of the parapet, at the interior extremity of the counterforts, to the level of the bottom of the ditch, where he excavated a chamber into the masonry of each counterfort, and loaded a chamber with eight and a half barrels of powder, as in fig. 89 : *b c*, shaft; *a*, chamber; *b*, *b*, *b*, *b*, action of the powder. The shaft was then filled up with clay or sand, and fired by means of a saucisson led through the stopping of the shaft to the top of the parapet. These mines exploded very irregularly, but, from the magnitude of their charges, utterly blew the forts to pieces.*

" In 1809, Lieut.-Colonel Johnstone destroyed the revêtement of the bastion of La Valiere of fort Bourbon, at Martinique, as follows, see figs. 90 and 91. (The shaded part shows the galleries.) The height of the revêtement at the salient angle of the bastion was thirty-eight feet, and the parapet rose eighteen feet above it, making a total height of fifty-six feet. The thickness of this revêtement, at its base, was ten feet, with counterforts twelve feet apart; the counterforts were six feet thick next the revêtement, five feet at their inner extremity, and six feet in length,

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* Calculating each barrel to contain ninety pounds, each of these chambers had a charge of seven hundred and sixty-five pounds; and as counterforts are usually from fifteen to eighteen feet apart, we have here seven hundred and sixty-five pounds of powder at every fifteen or eighteen feet, which was an excess of charge quite unnecessary.

"Colonel Johnstone perforated the face of the revêtement through the thickness of the wall, and formed five chambers in the clay at the inner extremity of the counterfort at the points 1, 2, 3, 4, and 5, and loaded them as follows:—1 with 180lbs—2 with 270lbs—3 with 360lbs—4 with 90lbs—5 with 180lbs.—This last charge (5) placed *under* the counterfort, as seen at fig. 91.

"The explosion blew down the entire revêtement for one hundred and forty-four feet in length of the right face, and for one hundred and forty-seven feet of the left face, except a portion of twelve or fifteen feet *a b*, which, though much injured, remained standing in the long space between mines three and four. The earth of the rampart behind the wall blown down, generally laid at an angle of 45°."

Had the revêtement thus destroyed been five feet thick at top, it is easily calculated that the one hundred and fourteen feet of the right face, and the one hundred and thirty-two feet of the left face, (including the masses of the ten counterforts), amounted to 103,650 cubic feet of masonry, which had one thousand and eighty pounds of powder expended in its demolition. The destruction of the revêtements at Menin, in 1774, by Cormontaigne, as related by Sir John Jones, (see his Sieges, vol. i. page 394), was as follows: see fig. 92.

"The height of the revêtement was thirty feet, and the counterforts fifteen feet from centre to centre, and the chambers of the mine were placed thirty feet distance from each other, so as to be in the centre of each counterfort; the charge was one hundred pounds, French, of powder, and the effect extended from mine to mine.

"On clearing away the rubbish in 1817, the foundations were generally found perfect to serve for new walls, but any portions of the counterforts or scarp wall which remained, were cracked in every direction.

"The galleries (the parts darkly shaded in the figure) were made three feet high and two and a half feet wide."

Calculating the four mines in the figure to have destroyed one hundred and twenty feet of the revêtement in length, and allowing that these revêtements were five feet thick at top and ten feet at bottom, there must have been a mass of six thousand seven hundred and fifty cubic feet of revêtement masonry destroyed by the action of four hundred pounds of powder: the line of least resistance to each charge averaging ten feet, besides which, it may be reckoned that nine counterforts were rendered unserviceable, making an additional mass of eight thousand nine hundred and ten cubic feet—in all, seventeen thousand six hundred and sixty cubic feet of masonry demolished by the action of four hundred pounds of powder.

At page 299, vol. ii. Sir John Jones's Sieges, is the following relation of the destruction of the piers and abutments of the flood-gates, at the entrance of the basin of the dock-yard at Flushing, in December, 1809, (see figs. 93 and 94).

"Four shafts (*e*) were sunk at the back of the wall supporting each half-gate, to a depth considered to be seven feet from the bottom of the foundation of the masonry; and, at that level, a gallery was run horizontally beyond the centre of the wall, so as to leave a line of least resistance, of seven feet, in the direction of the hinges and their abutments. At the extremity of the gallery, a return of two feet was made, and a chamber (*bc*) formed; the floor of which was six or seven feet above the bottom of the foundation of the piers.

"Each chamber was loaded with one hundred and twenty pounds of gunpowder, and the gallery was tamped for its whole length with bags filled with sand. This charge of one hundred and twenty pounds was apportioned, as being the smallest calculated as sufficient to effect the object of ruining the gates, from apprehension of doing injury to the houses on the quay, or the quantity of powder should have been one-half greater.

"The explosion was scarcely perceptible at a little distance, but it served completely to shake the wall and to rend it through in various places, as shown on the plan (by the darker shaded lines) though not to overturn it."

The line of least resistance was here seven feet; the total quantity of masonry injured is not named, but from a rough calculation, it is estimated at about one hundred and ninety-three thousand six hundred cubic feet, which took nine hundred and sixty pounds to produce the effect above named.

Detail of the destruction of the ramparts of Vienna in 1801.

The charges of powder used on this occasion, were calculated on the supposition that twenty pounds were required to destroy every six cubic feet of masonry. One of the bastions was forty-eight feet in height; shafts were sunk into its parapet to a depth of thirty-five feet, at from fifty-five to sixty feet apart: from the bottom of these shafts, two galleries were run out to form chambers against the back of the revêtement at about thirteen feet above the bottom of the ditch; these chambers were from twenty-eight to twenty-nine feet apart, abutted against a thickness of fourteen or fifteen feet of masonry; their charge was five hundred pounds each: the revêtement was completely overthrown in great masses, and the earth of the rampart formed a slope of easy ascent.

Another bastion had behind the escarp, a gallery of masonry eight feet in height and three feet in breadth, every where, nearly on the same level as the bottom of the ditch, and about thirteen feet distant from the exterior face of the revêtement. In this gallery was placed a charge of fourteen thousand pounds of powder, in different heaps, from one thousand to two thousand pounds, calculated according to the rule given of twenty pounds to every six cubic feet of masonry; the ends of the gallery were well tamped, and by the discharge, the revêtement was entirely overthrown without great violence or noise.

Another bastion was demolished in like manner; but the charge was augmented on account of the empty spaces and crevices in the gallery.

The most remarkable bastion had a revêtement of sixty-three feet in height, including the depth of the foundation and the heights of the parapets; the thickness of the wall at the base was nineteen feet and a half, and at the summit nine feet and a half. It had an escarp gallery six feet and a half high and of the same breadth, narrowed in different parts by the counterforts, which were placed at a distance of thirty feet from each other, and in which passages four feet wide were made. These counterforts also had a thickness of about twelve feet at the root, eight at the tail, and were twelve feet long. The vault of the gallery was two feet thick, and its piers three feet. Its bottom was five feet below the level of the ditch in the whole extent of the faces. In each counterfort there was a chimney or air-hole opening in the interior slope of the parapet; lastly it communicated with other galleries made under the the terre-pleine of the bastion. There was a charge of thirty-three thousand two hundred pounds of powder placed in this gallery, (although the calculation indicated thirty-seven thousand pounds). This charge was divided into eleven heaps, viz. one at the salient, one at each shoulder angle, three upon each face, and one in the middle of each flank: these heaps were connected together by great trains, which themselves consumed two thousand five hundred pounds of powder. All the issues of the gallery were exceedingly well tamped with beams and earth. The explosion of this enormous charge of powder entirely destroyed the revêtements; the mass of the masonry that was raised was thrown forward about fifty feet and broken into small pieces; elsewhere it was equally projected, but in greater fragments. Although the heap at the salient and at each shoulder angle had been increased, yet there remained little pyramids of masonry that were only shaken and much injured. The total height of the ravelins was thirty-five feet; the revêtement was divided into two parts by a berm five feet wide and twenty feet above the bottom of the ditch; shafts at twenty-four feet apart were sunk on the berm to a depth of eighteen feet, and chambers made to the right and left; each mine had a line of least resistance of twelve feet, and should have been loaded with a charge of three hundred pounds; but, as the charge had to be divided into two parts, and as the shafts were but imperfectly rammed, the charge was augmented to three hundred and fifty pounds; the demolition was complete.

Part of the counterscarp was destroyed by means of a gallery at its back; but on account of the numerous crevices and openings, as well as from imperfect tamping, the charge was made much more than the calculation indicated. The remainder of the counterscarp was destroyed in the usual manner by mines placed at the back of the revêtement: at the distance of twice the length of the line of least resistance from each other: for every two chambers a gallery was driven in perpendicularly to the revêtement, and branches made to right and left.

To demolish the curtains, shafts were sunk at twenty-four feet apart till within ten feet of the level of the ditch; from the bottom of each shaft, a branch was run out to meet the masonry, in which the charge was lodged, when it was found that the wall had more than twelve feet of thickness; and if less, the charge was lodged in the earth. The charge for each mine varied from two hundred and fifty to three hundred pounds. The branches were tamped with earth and turf, and the shafts merely filled in again. The explosion invariably produced complete destruction.

In this great work, where the miners were well paid, it was ascertained that in masonry of brick, they only made progress at the rate of three feet per day; and in masonry of hard stone, not more than one foot per day.

As another instance of demolition, the following relation is taken from vol. i. of Jones's Sieges, page 391, of the injury done to the defences of Almeida, by General Brenier, on the French garrison evacuating this fortress in 1810. Colonel Sir John Jones is of opinion that it "was very judiciously planned and very successfully executed." (See fig. 95).

"The fronts selected for destruction were those attacked by Marshal Massena, being next the Coa on the south-west, and which fronts have always been considered the weakest, in consequence of their scarps being much exposed to the fire of batteries from a height at a moderate distance, and also from their ramparts being too elevated to see, in a sufficient degree, the ground in their front.

" Along the *chemin des rondes* of these fronts, at intervals judged to be twenty-five feet, shafts were sunk to the depth of fifteen or eighteen feet close at the back of the escarp wall, (which is thirty feet in height), and chambers formed behind the counterforts on each side of the bottom of the shaft for the reception of cases of gunpowder. These being deposited and well secured from the effects of the moisture, the shafts were firmly tamped, and a saucisson led upwards from the gunpowder through the tamping, to the extremity of which a fuse or portfire was attached.

" The escarps of two fronts, with those of a face and two flanks of adjoining fronts, being thus prepared to be blown down by means of 150 fougasses, all the field guns, carriages, shot, implements, and military stores in the place, were ranged along the ditch at their foot. On the night of the 10th of May, at the moment of the evacuation, portfires, intended to burn till the rear-guard was well off, were lighted, and though the mines went of in very irregular succession, still they blew down the entire revêtement, some of it in pieces of enormous magnitude, (ten or fifteen feet square of superficies) other parts in smaller compact portions, and some as loose stones and rubbish. The mass thus thrown forward nearly filled the ditch, and buried or destroyed every thing which had been placed on its surface. The revêtement being overturned, the earth of the rampart behind it, loosened by the explosion, formed a very easy slope, and the ramparts of Almeida were for the moment laid completely open. The counterscarp, covered-way, and glacis, however, remained uninjured.

" Several shafts, left in an unfinished state by the French, were, by order of Sir Brent Spencer, completed and exploded, when he marched with his corps to the Alemtejo in the following month, and utterly demolished other considerable portions of the revêtement.

" In the performance of this duty, Lieut. Trench, the only officer of engineers with the corps, was, from the awkwardness of the uninstructed soldiers employed under him, blown to pieces; and, in consequence, no report could ever be obtained of the details of the operation, or of the quantity of powder used, nor of the exact distances of the French shafts, or the precise manner in which they applied the powder."

Although this instance of demolition is very interesting, yet no information can be drawn from it as a guide under similar circumstances.

In very tenacious masonry, it has been found that the lower part of the revêtement may be blown away, while the masonry of the upper part adheres together, with the earth behind it, like an irregular arch, especially when the charges are barely sufficient for demolition; or when they have not been lodged well back in the counterforts. Therefore, when it is desirable to destroy the revêtement completely, a line of holes for blasts may be made by a jumper or borer along the inner upper surface of the wall, which being fired a little before, or at the same moment as the mines below, will ensure the utter destruction of the wall.

Let fig. 96, from *a* to *d*, represent about twenty-five feet of the elevation of the back of a revêtement, supposing the earth from *a* to *b* to be bared in order to show the arrangement of forming the blasts. Suppose it four feet thick at top and twenty-five feet high. By a late experiment on a mass of masonry of these dimensions, by which it was completely destroyed, three mines were lodged at *f f f*, of about thirty-three or thirty-five pounds of powder each, and five holes, *h h h*, made by a jumper or borer, to do which, the earth was bared for four or five feet from the back of the wall, and the holes made at an angle of depression of 45°, four feet apart, and each loaded with five pounds of powder. The depth of the holes for these blasts exceeded by a little the thickness of the masonry, so that the line of least resistance was outwards; a powder hose, about the thickness of the forefinger, communicated from blast to blast, or from *h* to *h*. The blasts were first fired, exploding in quick succession, and destroying the upper part of the wall. The mines were then fired, completely demolishing the wall, and driving out some of the brickwork for forty or fifty yards, leaving a breach fit for a sub-division of twenty-five files to mount abreast.

To destroy a tower. If the tower has a diameter of eighteen feet or upwards, the wall is perforated from the inside, and mines are established, as seen in fig. 97.

Should the tower be connected to walls (*a b*), mines must be established in the walls near the solid points of junction *a* and *b*, where the greatest resistance would be offered to the effects of the explosion.

This differs a little from the mode of the destruction of a tower, related by Vauban. This tower, fig. 98, was thirty-six feet high, the walls ten feet thick, having a clear interior diameter of twenty feet; openings (*a b*) were made in the walls from the outside at one-third of the circumference from each other; hence branches were run in half through the wall, with returns right and left, each equal to seven feet; at the extremities c and *f*, were lodged one hundred and ninety pounds of powder, and at *d* and *e* one hundred and eighty pounds, in all seven hundred and forty pounds, to demolish about nine thousand cubic feet of masonry; which was satisfactorily done.

When a tower has only from twelve to sixteen feet in diameter, it will suffice to excavate a pit in the centre of the tower to about the depth of the foundations, and to place a charge there according to its line of least resistance; calculated from the centre of the mine to the exterior foot of the wall. The floor of the tower is covered with two rows of crossed beams, well fixed down by rests, placed against the masonry of the vaults. Thus Vauban destroyed a tower forty-five feet high, the walls eight feet thick, having a clear diameter of sixteen feet, that is, about six thousand four hundred cubic feet of masonry, by placing a charge of two hundred and fifty pounds of powder in a hole made in the ground in the centre of the tower.

When a pit cannot be excavated, from a wet foundation, and when the tower is loop-holed, which prevents the establishment of mines in the thickness of the walls, powder is placed upon the floor of the tower, and strongly secured above by beams of wood and sand-bags to form a resistance. Thus Vauban successfully destroyed a tower near Amsterdam, which was surrounded by water; see figs. 99 and 100.

The walls were six feet thick, and the interior diameter fifteen feet, and so pierced all round with loop-holes (*a a a*) for musketry and air-holes, as to render the construction of mines in the thickness of the walls impracticable ; a shaft could not be sunk below the floor on account of the water; but a timber chamber *O* was formed on the floor, twenty-four inches deep, and twenty inches square, to contain two hundred pounds of powder; it was well secured by logs of wood (figs. 99 and 100), placed transversely and by props against the roof and sides.

In a square tower having several floors, mines can be placed in the four angles on the ground floor, tamping the first floor.

To destroy powder magazines. A succession of mines are placed in the piers and springs of the arch of the magazine, so that their effects shall just cross each other.

When time presses, and the demolition must be quickly done, a heap of powder may be placed on the floor of the magazine, all the openings well barricaded and fired by a powder-hose being led without. In order to determine the quantity of powder, it has been recommended to calculate the quantity necessary for ordinary mines to overthrow a revêtement that would have the same thickness as the piers of the magazine, and the same developement of length as the walls. Augment the sum of these charges by one half, and place the whole in a single heap in the middle of the magazine.

As an example of this kind of demolition, the two following cases are given, as having been executed at Tortona in 1801.

One of the magazines was forty-seven feet long, thirty feet wide, and thirty-seven feet high under the key of the arch; the walls were eight feet thick. At a distance of nine feet, it had a wall to inclose it twelve feet high and seven thick. A charge of one thousand three hundred pounds of powder was placed in the centre of the magazine; all the openings of the building were firmly closed with planks and beams. The explosion razed the walls to the level of the ground, and threw them in great pieces to a considerable distance. A mass of the arch, about fifteen feet in breadth, was raised five or six feet, and fell again into the interior.

The other magazine was fifty-eight feet long and thirty feet broad; it was surrounded by a corridor or wall on three of its faces. It had a story; the ground-floor had very thick piers founded on rock. At each angle was placed a heap of four hundred pounds of powder on the story. The explosion overthrew the piers and walls, and tore them up in blocks from their foundations.

An easy mode of destroying buildings whose walls are only four or five feet thick, (and consequently too thin to admit of branches being worked into them, seeing that a miner requires two feet to work in), is to lay the charge in equal heaps along the bottom of the wall, either inside or outside, though outside will generally be the most convenient; and having done so, to throw up a bank of earth to cover the powder, of such a thickness as to double the thickness of the wall, and thereby cause the line of least resistance to be through the wall, which will ensure its demolition on the explosion.

The manner in which gunpowder may be used in the attack and defence of places in mining is so extensive, that it is impossible to embrace all that may be said on the subject, or the many examples that can be selected from military history of its application. For instance, in the well-contested war of houses of Saragossa in 1809, Colonel Napier says, at page 44 of his Second Volume), " A mine under the University was loaded with 3000lbs of powder," and a little further on he adds, "16,000 shells thrown during the bombardment, and the explosion of 45,000lbs of powder in the mines, had shaken the city to the foundations."

In conclusion, we find that the action produced by the explosion of gunpowder, has afforded engineers many interesting theories and experiments. Mouzé has asserted, that a surcharged mine, or globe of compression, renders the usual extent of tamping unnecessary, as it can be made up by an augmentation of charge. His theory and experiments, however, require farther illustration. It is sufficient here to state the principal results on this subject, which are the experience of General Marescot, viz. :—

Charge.	*Tamping.*
Ordinary, or fixed at one.	Ordinary, or equal one.
Augmented one and a quarter.	Reduced to two-thirds.
Ditto one and a half.	Ditto to one-third.
Double charge.	Suppressed.

235. In Herschell's preliminary discourse to the study of natural philosophy, there is the following passage: " In the granite quarries, near Seringapatam, the most enormous blocks are separated from the solid rock by the following process: the workmen having found a portion of the rock sufficiently extensive, and situated near the edge of the part already quarried, lay bare the upper surface, and mark on it a line in the direction of the intended separation, along which a groove is

cut with a chisel about a couple of inches in depth; along this groove a narrow line of fire is then kindled, and maintained till the rock below is thoroughly heated, immediately on which a line of men and women, each provided with a pot full of cold water, suddenly sweep off the ashes, and pour water into the heated groove, when the rock at once splits with a clean fracture. Square blocks of six feet in the side, and upwards of eighty feet in length (and such a block would weigh four and five hundred thousand pounds) are sometimes detached by this method."

236. *On the defensive advantages to be derived from rivers, streams, canals, &c.* In order to secure these advantages for general purposes, it becomes necessary to have possession of the water courses; the points where the rivers and canals unite; the sluices by which the water is regulated; and of all that can place, in the hands of the defenders, the means of navigating at will, and of increasing or decreasing the volume and flow of the water.

237. Water may indeed be said to form the natural fortification of low countries, and of vallies, cut by streams or rivulets; and to benefit fully by such aids, it is necessary to possess a thorough knowledge of their course; their volume; their regular or irregular flow; their depth; and the nature of their beds; in order to determine the kind of fortification best suited to profit by their peculiarities.

238. Water courses are either parallel, oblique, or perpendicular to the frontier on which operations are carrying on; if parallel, they cover it; if otherwise, they either come from, or flow towards, the enemy; and, accordingly, require different dispositions in the fortifications situated upon them, to render them as useful as possible.

239. Fortifications situated upon rivers, especially at their confluence, or on islands, secure the advantage of protecting or cutting the navigation, and of giving to the defensive army the means of acting upon both banks. If a river be parallel to the frontier, the places constructed on its banks will aid the passage

of it, either to penetrate beyond it, or to secure a safe retreat across it.

240. Fortifications so situated as to draw a natural defence from water, are difficult to attack and easy to defend, in proportion to their degree of inaccessibility; as in cases of being covered by marshy or inundated ground, that cannot be drained, and which is only crossed by narrow causeways, commanded by numerous direct and oblique batteries. Philipsbourg and Peronne are examples of this: Mantua is in the midst of a lake. Valletta and Gibraltar are nearly surrounded by the sea, and offer only a small portion of the enceinte to be approached by land.

241. Fortifications upon rivers have their defensive properties greatly augmented when they can make use of the water to multiply obstacles by cuts and ditches, or to increase inundations that cannot be drained, or drained only by great labour and time; for the attention of the garrison is then confined to the defence of the accessible fronts. When the river is considerable, and its bed has much slope, it affords the means of introducing currents of water into the ditches, which are most useful towards the end of the siege. The fortresses of Strasbourg, Landau, Mauberge, Valenciennes, &c. have the advantage of being traversed by rivers, the water of which can be made to flow through ditches with great ease.

242. A fortress situated on the sea-shore, or at the entrance of a harbour, (as Portsmouth), possesses the advantage of being able to fill the ditches with water by sluice gates on the flowing of the tide; and either to retain the water in the ditches by the batardeaux, or to permit it to flow off, on the ebbing of the tide: fortifications on rivers, within the influence of the tides, have the same advantage.

243. Inundations that can be extended to a distance, oblige an enemy to weaken himself by extending his lines of circumvallation (paragraph 248) when he invests the place; they also interrupt the free communication between his different

quarters, and thereby enable the defenders to act more vigorously and successfully by sorties.

Inundations render the fronts they cover nearly inaccessible, as they can only be approached by boats: and, the fronts adjoining these inundations can, generally, have many of the faces of their works directed towards the water, so as to deprive an enemy either totally, or in part, of the advantage of establishing enfilading batteries against them; as to do so, he must be able to aline himself on the prolongations of the works, which, in this case, fall into the water.

244. Inundations are said to have the disadvantage of producing malaria and disease; and also, that they render it difficult to carry succours to a besieged place; as the enemy can easily command the few approaches to it.

245. *Inundations.* Let fig. 101 represent a fortress with a river flowing through it: the current running as the arrow indicates: the ground being elevated on the fronts *K* and *L*, as shown by the shading of the hills; and low on the sides *I*, *M*; let *A* be the bridge across the river; if the arches be blocked up so as to stop the current, the water will augment in the bed above it, and overflow all the low country at *M M*, and form an inundation, making the fronts about *C* and *B* inapproachable by a regular attack. An enemy has then only the middle fronts *K* and *L*, or the low fronts *F G*, against which to advance. If he should choose the latter, he could be much incommoded there by the sudden removal of the barrier, at *A*, by which, a greater body of water would be forced into the bed of the river than it would be capable of containing at its low banks *I*, *I*, which would be overflowed (in the direction of the dotted line) to the ruin of the besiegers' magazines and trenches. Thus the water of a river, under these circumstances, can be employed to force an enemy from its banks both above and below the place, and to oblige him to attack the intermediate fronts *K* and *L*, which have been previously strengthened by great ravelins, countermines, &c.

Should the measure of flooding the ground at *I* have been resorted to, the barrier *A* may be re-established, and the inundations above (at *M*) formed anew, in order to interrupt the investment; this artificial lake may even be sufficient, in some cases, to permit armed boats to navigate it and to disturb the assailant; and even to offer dry spots or islands, on which to form advanced posts or batteries of great importance.

Sometimes when an inundation rises to a great height, it finds an issue by one or two sides, and going round the city will seek its own bed again; this would manifestly render a place more secure against the enterprizes of an enemy: this, however, rarely occurs, as the banks of rivers are usually higher than the dike constructed to form the inundation; so that when the water rises to its summit, it flows over and runs into its bed. The dike in this case, fig. 101, is supposed to be formed by blocking up in whole, or in part, the arches of the bridge *A*, which renders such a dike secure against any attempt of an enemy to destroy it by shells.*

246. *Currents of water in the ditches.* To secure this advantage, in the case supposed in the foregoing paragraph and in fig. 101; the sluices *B* and *C* should be hidden from the enemy's view and covered by bomb-proof vaults. These batardeaux should be higher than the dike *A*, that when the water flows over the latter, it may not pass over the former into the ditches. The other sluices *F G* serve to retain the water in the ditches, or to allow it to escape, as may be judged proper. An intermediate batardeau may be constructed, as *H*, to procure means of augmenting the current.

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* In fig. 29 there is an instance of a small inundation made by the French at Badajoz, by forming a dam of the bridge leading across the stream Rivillas, (at the gorge of the lunette *R)*, which prevented all direct access to the front *g h*, that was breached from the British batteries, *P*, &c; but the columns, *z z*, for assault, were formed on the other side of the inundation, and penetrated to the breaches, by passing into the covered-way on the west side of this water, and this frustrated its object.

In order to preserve a current of water through the city for the benefit of the inhabitants, especially for the mills, a little canal DE is constructed to allow the water to flow by the sluice D which is made to open and shut at will: it serves also as an outlet on sudden overflowings of the river. In order to open the sluice gates easily and quickly, Bousmard (an eminent French author on fortification) recommends the following contrivance: see fig. 101. Between two piers, let the gates N, O, turn upon a pivot P which is nearer to N than to O; the parts NP and PO being unequal, they do not support an equal pressure of water, (which is supposed to press against the gates in the direction of the arrows). Let r be a little sliding flood-gate, which being raised up admits the rush of the current sufficiently to cause the greatest pressure to be on NP which will then swing (as may be seen by examining the construction of the piers) in the direction NS carrying O towards Z: abutments being made at S and Z to stop the gates. In order to shut the gates, close the little door r, and, with a little aid, it will easily swing round again into its original place.

CHAP. X.

On the attack.

247. To enter upon the strategical movements of an army previous to undertaking a siege would be quite out of place in a treatise of this kind; but for the information of the pupil, it becomes necessary to observe, that the forces about to undertake a siege must have the lead and superiority in the field; for the corps appointed to conduct the duties and details of the siege, as also the investing corps (or that which surrounds the whole place and hems in the garrison on every side) ought not to be liable to have their operations disturbed and defeated by an

Montcallier, after a loss of 8000 men. By this enterprise, Eugene made himself master of the whole of Italy.

248. "The army intended to *invest* a place, approaches it when least expected, and occupies positions simultaneously on every side, so as to cut off all its means of communication with the country. The positions thus occupied are strengthened by good field-works, and a sure communication is kept up between them. In examining the many sieges carried on in the seventeenth and eighteenth centuries, we cannot but be struck with the immense developement of lines between which the investing army generally secured itself. In order to repel any attack from an army endeavouring to succour the place from without, it was customary to construct a belt of strong field works about two or three miles from the place, facing the country; this was the line of *circumvallation;* and a similar concentric belt of field-works facing the place, was the line of *contravallation*, constructed to secure the investing corps against any enterprise of the garrison. This mode of proceeding is very ancient; it was thus that Cæsar entrenched himself with 60,000 men before Alexia, and successfully defended his lines of circumvallation when attacked by 242,000 Gauls, and those of contravallation against an attack of 80,000. These lines appear to have consisted of a good ditch, from nine to fifteen feet in width and depth, fenced on the inside by the mound of excavated earth; and outside of the ditch strengthened by an abattis, or strong felled trees, (paragraph 326).

249. "It is absolutely necessary to *invest* the place to be attacked; that is, to surround it with troops; and, if necessary, by lines of fieldworks, so as to prevent the garrison holding any intercourse with the neighbouring country; for it is evident, that if this precaution be not attended to, the defenders may be able to draw fresh supplies of men, provisions, and ammunition from the country, and the assailants will labour under the disadvantage of attacking these renewed means on two or three fronts of fortification, and thus waste their

superiority, which chiefly consists in their capability of bringing up numbers and means of attack continually, while those of the besieged, however efficient at first, must in time diminish and ultimately be rapidly expended. A place may be reduced by investment or blockade alone, and in some instances, where it is possible suddenly to blockade a place ill provisioned and filled with numerous garrison and population, it may be the most ready and bloodless mode of proceeding. Indeed, many other circumstances may render it desirable to endeavour to reduce a place by blockade.

" At page 5, vol. ii. of Jones's Sieges, we read that on the 1st of July, 1813,

" The Marquis of Wellington, attended by Sir Richard Fletcher, reconnoitred *Pamplona* to decide the point of attack, and give the necessary orders for commencing the operation (that was the siege).

" The works, however, appeared in such good order, and the river so effectually shielded one side of the town, and the citadel so covered the other, that the garrison being known to exceed 4000 men, and having upwards of 200 pieces of ordnance to aid their defence, neither the force which the army could spare, nor the means it could command in ordnance, stores, or materials, were judged sufficient to ensure its reduction. In consequence, the Marquis of Wellington decided to substitute a close blockade for a siege, &c.

" For the more effectual confinement of the garrison of Pamplona, and to strengthen the front of the blockading corps, the Marquis of Wellington ordered works to be thrown up all round the place, on the nearest heights favourably situated to command the several roads and communications. Nine redoubts, calculated for garrisons from 2 to 300 each, were, in consequence, immediately marked out by Sir R. Fletcher, on commanding points from 12 to 1500 yards from the fortress. The redoubts were ordered to be made of a strong profile, and to be armed with the French field-guns captured at *Vittoria*, firing through embrasures. The whole chain of redoubts was speedily in a state of defence. Garrisons were allotted to the several works, which were kept in them constantly prepared to receive and repel any attack; but the remainder of the blockading force was either placed under cover in the villages, or bivouacked on favourable spots just without the fire of the place; the whole however being in constant readiness to form under arms, at their several alarm-posts, on the first intimation of the garrison making a sortie.

"In the middle of July, Marshal Soult advanced with a very strong force to the relief of Pamplona; the British and Portuguese forces were concentrated in the Pyrenees to oppose him, and the blockade was entrusted to a force of Spaniards not exceeding 8 or 9,000 men.

"Under these circumstances, increased exertions were made to strengthen the several defences of the blockading line.

"Several buildings near the place were barricadoed and formed into strong advanced posts, the passage along the roads was obstructed in various places, fleches were thrown up to protect the guards, and signal-posts were established to communicate intelligence and orders round the whole blockading circle.

"At this period, when the army of Marshal Soult had penetrated to within a few miles of the fortress, and a desperate sortie might naturally be expected, all the advanced posts were reinforced at night, and chains of sentries were pushed out in advance, to guard against surprise or the passage of an individual, and the whole blockading force remained under arms, prepared to repel any powerful sortie. These precautions succeeded in preventing a single communication of any kind passing between the garrison and the force engaged for their relief, on the 28th, 29th, and 30th July, almost within view of the ramparts.

"This blockade is probably a solitary instance of the investment of a large place, situated close to its own frontier, having been so successfully maintained for the long period of three months, as to preclude the garrison from once communicating with, or receiving intelligence from their friends.

"History furnishes us with numerous examples of places that could not have been reduced by any other process than by starvation arising from a strict blockade: we have quoted this recent instance of Pamplona to illustrate the term *blockade*, and to show the opinion of our great leader the Duke of Wellington, on this occasion; and in the investment of the other sieges undertaken by him, strong redoubts and posts were preferred to the old method of connected lines of circumvallation and contravallation.*

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* "There are only two ways of ensuring the success of a siege; the first, to begin by beating the enemy's army employed to cover the place; forcing it out of the field, and throwing its remains beyond some great natural obstacle, such as a chain of mountains or a large river. Having accomplished this object, an army of observation should be placed behind the natural obstacle, until the trenches are finished and the place taken.

"But if it be desired to take the place in presence of a relieving army without risking a battle, then the whole *materiel* and equipment for a siege are necessary to begin with, together with ammunition, and provisions for the presumed period of its duration, and also lines of contravallation and circumvallation, aided by all the localities of heights, woods, marshes, and inundations.

"Having no longer occasion to keep up communications with your depôts, it is now only requisite to hold in check the relieving army. For this purpose, an army of observation should be formed, whose business it is never to lose sight of that of the enemy, and which, while it effectually bars all access to the place, has always time enough to arrive upon his flanks or rear, in case he should attempt to steal a march.

"It is to be remembered, too, that by profiting judiciously by the lines of contravallation, a portion of the besieging army will always be available in giving battle to the approaching enemy.

"Upon the same general principle when a place is to be besieged in presence of an enemy's army, it is necessary to cover the siege by lines of circumvallation.

250. When the defenders have been driven within their works, and the place invested, the ground before the fronts is well examined,* and the most suitable situations selected for *the park of artillery* and *the engineers' park*: the former to receive all the ordnance stores and ammunition; and the latter, all the engineer stores and materials to be used in the construction of the trenches and batteries, &c.: these parks should be removed beyond the general range of the artillery of the fortress, and placed behind the slopes of hills or in ravines, but with a ready access to the trenches and batteries of attack, for the use of which they are formed.

At page 176. vol. ii. of Journals of Sieges, Sir John Jones has the following remarks on the engineers' park.

"The park was usually formed in the most convenient spot, concealed from the view of the place by some rising ground, at

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" If the besieging force is of numerical strength enough (after leaving a corps before the place of four times the amount of the garrison), to cope with the relieving army, it may remove more than one day's march from the place; but if it is inferior in numbers, after providing for the siege as above stated, it should remain only a short day from the spot, in order to fall back upon its lines if necessary, or receive succours in case of attack.

" If the investing corps and army of observation are only equal when united, to the relieving force, the besieging army should remain entire, within or near its lines, and push the works and the siege with the greatest activity."—*Military Maxims of Napoleon.*

* Localities sometimes greatly favour the assailants; for example, in the second volume of Journals of Sieges by Sir John Jones, it is stated that, on the close investment of Bayonne by the Duke of Wellington, in February, 1814, " a road forming almost a parallel to the new works, at two hundred and forty yards in their front, served as a communication along the centre of this line, and by means of traverses, walls, &c. was converted into a beautiful covered-way, along which, and the houses in its front, the pickets were lodged.

" The troops during the blockade bestowed considerable labour in strengthening these advanced parts; and although the garrison cannonaded them frequently, they never succeeded in dislodging a single picket."

the distance of eighteen hundred or two thousand yards; care being always taken to select a ravine from which the communications from the rear to the park, and from the park to the trenches, should be practicable in the worst weather and easily to be found in the dark.

"The officers of engineers, the officers acting as engineers, the men brigaded as sappers, miners, and artificers, and the field-train commissariat, encamped or bovouacked in a regular manner, in the vicinity of the commanding engineer's tent; and the tools, fascines, gabions, platforms, splinter-proof timbers, scaling ladders, sand-bags, small stores, &c. &c., as brought into the park, were regularly piled, or arranged in rows of fixed numbers, so as to be counted in a moment, or a demanded number issued without confusion in the dark.

"The saw pits and places of work for the carpenters, the forges for the repair of tools, and the spaces for re-tying and re-making damaged fascines and gabions, and generally for every species of labour which could be performed out of the trenches, were also established within the park boundary line, for the convenience of overlooking the workmen, and the security of the materials.

"Unless the situation of the park be extremely well concealed, eighteen hundred yards is rather too near the place; for at Badajos, at that distance, the rolling shot and occasional shells which came into the park were a source of considerable annoyance; and it should not be forgotten that the cavalry of the garrison in a sortie absolutely rode through the park, and had the opportunity of burning the whole supply of fascines, gabions, &c.

Entrepot.

"A little in the rear of the mouth of the trenches, an entrepot was established, at which a noncommissioned officer attended, for the purpose of collecting stray and broken tools from the trenches; and every thing returned from the trenches to the park was, in the first instance, deposited in this entrepot, till it could be sent for at a convenient moment by a working party from the park.

"This arrangement had its origin at Ciudad Rodrigo, in consequence of its being a great delay and additional fatigue to the troops relieving at mid-day, to make the detour of the engineers' park to deposit the returned tools and stores.

"Such an entrepot will however, under all circumstances, be found of the greatest use."

The trenches are generally opened at a distance of six hundred yards from the place: and as the engineers' park is usually at a distance of one thousand eight hundred or two thousand yards, an entrepot becomes necessary, of which Sir J. Jones speaks, at page 178. vol. ii.; in the article just quoted.

251. The pupil is referred to the preliminary observations on the attack of fortresses by Sir John Jones, in the 1st vol. of his Journals of Sieges, all of which would willingly be transferred into these pages, did not want of space forbid a longer extract than the following.

"The first operation of a besieger is to establish a force equal to cope with the garrison of the town about to be attacked, at the distance of six or seven hundred yards from its ramparts.

"This is effected by approaching the place secretly in the night with a body of men, part carrying entrenching tools, and the remainder armed. The former dig a trench in the ground parallel to the fortifications to be attacked, and with the earth that comes out of the trench raise a bank on the side next the enemy, whilst those with arms remain formed in a recumbent posture in readiness to protect those at work, should the garrison sally out. During the night this trench and bank are made of sufficient depth and extent to cover from the missiles of the place, the number of men requisite to cope with the garrison, and the besiegers remain in the trench throughout the following day in despite of the fire or the sorties of the besieged. This trench is afterwards progressively widened and deepened, and the bank of earth raised till it forms a covered road, called a parallel, embracing all the fortifications to be attacked; and along this road guns, waggons, and men, securely and conveniently move, equally sheltered from the view and the missiles of the garrison. Batteries of guns and mortars are then constructed on the side of the road next the garrison, to oppose the guns of the town, and in a short time, by superiority of fire, principally arising from situation, silence all those which bear on the works of the attack. After this ascendancy is attained, the same species of covered road is, by certain rules of art, carried forward, till it circumvents or passes over all the exterior defences of the place, and touches the main rampart wall at a spot where it has been previously beaten down by the fire of batteries erected expressly for that purpose in the more advanced parts of the road.

"The besiegers' troops, being thus enabled to march in perfect security to the opening or breach in the walls of the town, assault it in strong columns, and being much more numerous than the garrison defending the breach, soon overcome them, and the more easily, as they are assisted by a fire of artillery and musketry directed on the garrison from portions of the road only a few yards from the breach; and which fire can, at that distance, be maintained on the defenders of the breach till the very instant of personal contention, without injury to the assailants. The first breach being carried, should the garrison have any interior works, the covered road is, by similar rules of art, pushed forward through the opening, and advanced batteries are erected in it to overpower the remaining guns of the place; which effected, the road is again pushed forward, and the troops march in security to the assault of breaches made in a similar manner in those interior works, and invariably carry them with little loss.

"To preserve the life of a single soldier is, however, always an object; therefore, when time is abundant, the loss of the few men attendant on the assault of breaches under these favourable circumstances is avoided; as, by a small delay, the covered road can be equally well pushed up and through the breach, without giving the assault, as after the breach has been carried; and thus, by art and persevering labour, the strongest and most multiplied defences frequently fall without any exertion of open force.

"From the foregoing description it will readily be conceived, that the most important object at a siege is to carry forward the covered road to the walls of the place, and that all the other operations are secondary to, and in furtherance of, such an advance; and consequently, that the efficiency of armies at sieges depends on their ability rapidly to complete the road, and at a small expense of life.

"To enable the general reader to form his own judgment on the means necessary for such efficiency, it should be stated, that the formation of the covered road is attended with different degrees of difficulty in proportion as it advances.

"At its commencement, being at the distance of 600 yards from the fortifications and not straitened for space, the work can readily be performed by the ordinary soldiers of the army. The second period is, when the road arrives within a fair range of musketry, or 300 yards from the place; then it requires particular precautions, which, however, are not so difficult, but that the work may be executed by soldiers who have had a little previous training. The third period is, when it approaches close to the place—when every bullet takes effect—when to be seen is to be killed—when mine after mine blows up the head of the road, and with it every man and officer on the spot;—when the space becomes so restricted that little or no front of defence can be obtained, and the enemy's grenadiers sally forth every moment to attack the workmen, and deal out destruction to all less courageous, or weaker than themselves.

"Then the work becomes truly hazardous, and can only be performed by selected brave men who have acquired a difficult and most dangerous art called sapping, from which they themselves are styled sappers.

"An indispensable auxiliary to the sapper is the miner, the exercise of whose art requires even a greater degree of skill, courage, and conduct, than that of his principal. The duty of a miner at a siege is to accompany the sapper, to listen for and discover the enemy's miner at work under ground, and prevent his blowing up the head of the road, either by sinking down and meeting him, when a subterraneous conflict ensues, or by running a gallery close to that of his opponent, and forcing him to quit his work by means of suffocating compositions, and a thousand arts of chicanery, the knowledge of which he has acquired from experience. Sappers would be unable of themselves, without the aid of skilful miners, to execute that part of the covered road forming the descent into the ditch, and in various other portions of the road, the assistance of the miner is indispensable to the sapper: indeed, without their joint labours and steady co-operation no besiegers' approaches ever reached the walls of a fortress.

"A siege, scientifically prosecuted, though it calls for the greatest personal bravery, the greatest exertion, and extraordinary labour in all employed, is beautifully certain in its progress and result. More or less skill or exertion in the contending parties will prolong or shorten in some degree its duration, but the sapper and the miner, skilfully directed and adequately supported, will surely surmount every obstacle. On the contrary, the sieges of armies destitute of these capable and confident auxiliaries, are hazardous in the extreme. Their only chance of success is in scrutinizing the exterior of a fortress to discover some spot from whence, in consequence of the irregularity of the ground or faults of construction, the main escarpe wall can be seen at a distance sufficiently great for ordinary soldiers to approach with the covered road, and there establish batteries to form an opening through the wall into the place.

"That effected, the troops must advance to the assault of the breaches as in the 16th century, losing the shelter of the covered road at the moment the fire of the place becomes most powerful and destructive; whereas, the fire of the besiegers' distant batteries being necessarily suspended to avoid killing their own storming party, the garrison can, with impunity, mount on their parapets and use every kind of weapon and missile in their defence.

"Should the columns, under these disadvantages, arrive in good order at the brink of the ditch, they must descend into it, down a wall from fourteen to sixteen feet in depth, which cannot fail to break their order, and throw them into confusion. No fresh formation can be attempted, in a spot where death is incessantly showering down on the assailants, and they rush to the breach more like a rabble than a solid column.

"From this moment, success hinges on the individual and confident bravery of the officers and troops, and the unshrinking firmness of the commanding general in encouraging and supporting their efforts.

"These qualities, when united in a high degree, may obtain success at a considerable sacrifice of life; but whenever such nature of assault has been attempted under ordinary circumstances and feelings, in former or recent wars, repulse has invariably been the consequence."

252. Previously to entering upon the details sketched in the foregoing paragraph, it is proposed to describe some of the materials used by the engineers, and the manner in which they execute their offensive works.

1. The construction of fascines.
2. Ditto of gabions.
3. Ditto of sand-bags.
4. Ditto of batteries.
5. Ditto of field powder magazines.

The pupil has already had the nature and object of the three first, viz.: fascines, gabions, and sand-bags, explained from paragraphs 73 to 80, to which he is referred.

Fascines are usually made of good strong brushwood laid in a bed or cradle of tressels, as seen in fig. 102, where the tressels *a b* are at about four feet apart: two levers, united by a rope or chain about four feet in length, are used to choke the fascine, by being passed round it, and pressed by men on opposite sides, till the brushwood is about nine inches in diameter; for which purpose there are two marks on the rope or chain, at fourteen inches on each side of its centre, (that is twenty-eight inches apart), and the fascine is increased or diminished in substance till these marks meet in choking it closely: before the *choker* is removed a strong withe or *binder* is passed round the place, where it is compressed and firmly fastened: these binders are at about eighteen inches apart, and much of the goodness of the fascine depends on their strength and fastening.

Fascines are made of various lengths and diameters, according to the required purposes; but the usual dimensions are eighteen feet long, and nine inches in diameter; such a fascine would weigh about one hundred and forty pounds, and can be made by five men in one hour, including the cutting of the material when at hand in a wood. With the fascines, bundles of strong pickets are prepared, in the proportion of six to each fascine: the pickets should be about four feet long, and one and a half inches in diameter; and are used to fix the fascines into the earth, and to each other, as they are built up to form a revêtement.

Besides these long fascines, (or, as they are often called, saucissons), there are shorter and smaller fascines used in carrying on the work of the trenches at a siege. These *trench-fascines* are about four or five feet long and six inches thick: there are also thick fascines of eighteen inches in diameter, and from six to nine feet in length, called *water-fascines*, used to cover a wet surface: and in crossing wet ditches, they are sunk with stones in layers to form a causeway, (paragraph 297). A small kind of fascine is used in sapping, called a *sap-faggot*: they are usually three feet long, and nine inches thick, having a strong sharp-pointed stake through their middle to fix them into the ground.

In constructing a field work, the number of fascines required to revêt is readily found by the following rule:

Divide the length of the work by the length of the fascines, and divide the height of the work by the thickness of the fascines; then multiply the two quotients together for the number required.

253. *Gabions*, or cylindrical baskets, open at top and bottom. To construct these well, the men employed must be acquainted with basket work in all its parts.

Gabions are of various dimensions, according to their intended use. When required to revêt the steep interior slopes of batteries, two upright rows of them should equal the full height of the parapet; in this case, the basket work is strongly and rather coarsely made; but in the sap-gabions the work is carefully *waled* and finished. The gabions used in the late siege of Antwerp are said to have weighed forty-five pounds each.

To construct a *sap-gabion*, as in fig. 103, a circle of twenty inches in diameter must be traced on a clean hard level piece of ground: each quarter of the circle is divided into five parts, and small holes made at the points of division, to receive straight uprights of three feet and a half in length, around which the withes of the basket work are *waled*, as seen in fig. 103. When finished, the gabion is two feet nine inches high, the ends of the uprights are cut off, and the work is firmly stitched together from top to bottom in several parts. A sap-gabion, carefully made and finished, generally weighs about twenty pounds, and occupies four men for one hour.

Circular boards of the dimensions seen in fig. 103 have been used, and are recommended, on which to form the gabions.

The *sap-roller* used at the field engineer department, (at Chatham, under the directions of Colonel Pasley), is represented in perspective, in fig. 104: it consists of two concentric gabions each six feet long: the greater one has a diameter of four feet, and the lesser one of two feet eight inches; both these baskets are very strongly made, and the interval between them is stuffed with pickets of hard wood, not less than one inch thick, which renders it musket proof. It occupies eight men for twelve hours to make such a sap-roller.

254. *Hurdles* are useful in temporary works, to retain earth at a steep slope for a short time, &c.; they are usually made three feet high, and from six to nine feet long: they are handy in the trenches, especially in wet weather, to form a firm footing, and enter into the construction of the passages of wet ditches, (paragraph 297). At the siege of the citadel of Antwerp, in the winter of 1832, the ground of the trenches was so inundated and rotten as to require layers of fascines and hurdles to give it solidity.

255. At page 192, vol. ii., of Sir John Jones's sieges, the following judicious remark is made:—" No general rule for the size of materials and implements can be laid down; but in arranging the dimensions of fascines, gabions, splinter proofs, &c. for any service, it behoves a British officer to consider well the nature of the trees and shrubs to be found in the country where the army may be acting, or otherwise following the rules taught in books, he will find himself occasionally in a sad dilemma. For instance, in the early part of the war it happened, in making the preparations for the attack of a post in the West Indies, the superior density of the wood, peculiar to tropical climates, not being adverted to, the fascines and gabions were prepared of the usual dimensions, and, in consequence, none of the original supply could be made available in the trenches from their great weight.

" Fascines and gabions made in summer will also weigh more than those made of similar boughs in winter.

" Where brushwood or other material is scarce, or difficult to be procured, it should be recollected that the content of fascines of equal lengths, being as the squares of their diameters, much will be saved by making them of small bulk.

256. *Sand-bags* are extremely useful for revêting the steep interior slope of field batteries, &c.: they will retain earth at a slope of about one fourth; and as they are intended for very temporary purposes, the canvass of which they are made may be very coarse. When the soil on which a lodgment is made is rocky and bare, bags of sand are thrown into gabions to give cover. These bags are usually made up in bales of about two hundred each: their dimensions are as follows:

Empty.			*Full.*	
2 feet	8 inches	long	2 feet	3 inches
1	2	broad.	1	0
0	0	thick.	0	7

Sand-bags do not make a good lining for the cheeks of embrasures, as the bags burst from the explosion and take fire.

257. Bales of cotton, woolpacks, bags of hay, &c., stuffed into gabions, serve to obtain a temporary cover from a musketry fire; but these, as well as fascines, are apt to take fire when there is not a sufficient quantity of soil to fill and cover them: thus, in the attack upon the Havanna by the British in 1762, the same parapets of fascines were burnt twice.

258. When a parapet is constructed to furnish a close musketry fire against a work, and is therefore itself exposed to the same, it is customary for both parties to cover their men as much as possible, by forming loop-holes for them to fire through; this is done either by gabions or sand-bags: the gabions for this purpose are in the shape of frustrums of cones, about twelve inches high; twelve inches in diameter at top and nine inches at bottom: so that when filled with earth and placed close to each

other on their small ends, they meet at top and leave a small loop-hole for the musketry to fire through, and thus cover the heads and shoulders of the men: sand-bags for loop-holes are about nine inches in diameter and eighteen inches long; two are placed so near as to leave a small opening between them, and a third on top resting its ends on the two beneath.

259. *On the construction of batteries.* Batteries are of four kinds: 1*st. cavalier batteries*; 2*d. elevated batteries;* 3*d. sunken batteries; and* 4*th. half sunken batteries.* The first has the platform for the gun carriage above the level of the ground; see fig. 105: this construction is rare, as it involves great labour, requiring a large excavation (*a* to furnish the mass of earth *b*) and many workmen to execute it. An elevated battery is a complete parapet, the platform for the gun-carriage being laid on the level of the ground, as in fig. 106; this construction is in most general use, and is less laborious than that of the cavalier battery. A sunken battery has its level below the ground line, so that the gun can range just above it, as seen in fig. 107; the labour of the construction of this kind of battery is less than that of the elevated kind, as the solid earth below the ground line forms a portion of the parapet: and when guns are fired with an elevation, (as in the case of ricochet) this ready and quick construction is greatly approved: the depth of the excavation for the interior must depend on the height of the carriages upon which the guns are mounted: it should be deeper in rear than in front, that it may be drained.* A half sunken battery has both an interior and exterior excavation to furnish earth for the parapet: the interior excavation is not so deep as that of a sunken battery. The interior slopes of these batteries, and the cheeks of the embrasures, must be supported by field revêtements of gabions, fascines, or sand-bags.

260. In the 2d. vol. of Sir John Jones's Sieges, at page 170, there is an interesting and instructive memoranda as to the

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* The four-gun battery in front of Addiscombe House, constructed by the gentlemen cadets, is a very good specimen of a sunken battery.

manner of carrying on the duty and performing the work at the sieges in Spain; in which he says "The best lining for embrasures are the 18 feet fascines, as when revêted with sand-bags, the bags constantly burst from the explosion and take fire. It was found an excellent expedient to form the interior of the cheek of the embrasures, that is, the part of the opening next the gun, with very strong gabions, made larger than the ordinary size, and placed so close to each other, as only to admit the muzzle of the gun between them. This, besides giving great strength to the interior angles, protected the gunners very much from the enemy's musketry.

"In fact, after a few hours of the quick firing, which is now practised from heavy guns of iron, the embrasures become utterly shapeless beyond the muzzle of the piece, and all that can be hoped is to preserve two or three feet of tolerable cover next the interior of the battery. During these sieges, the embrasures of the several breaching batteries were fresh lined every night; and though every expedient was adopted to give them strength, still they were invariably found on the ensuing evening to have returned to a shapeless hole.

"The embrasures were placed 20 feet from centre to centre, when the space for the battery was not confined; but 18, or even 16, feet will be found a sufficient distance when saving of space is an object.

"Most of the batteries at these sieges were thrown up in a solid mass, and the embrasures cut through when the guns were mounted, in consequence of the destructive fire to which they were exposed; but where the fire on a battery was moderate, it was found most expeditious to form the embrasures simultaneously with the parapet."

In the relation of the siege of the citadel of Antwerp in 1832, published in the 52d number of the *United Service Journal*, it is stated "that in all the batteries not exposed to direct fire of cannon, the embrasures were furnished with thick musket-proof wooden shutters, opening vertically in their centre, and mounted on frames, with iron hinges and handles. These were opened to point and fire, and immediately closed on the recoil of the piece.''

261. In batteries exposed to a heavy fire, especially of shells, it is necessary to provide as much cover as possible for the men serving in them: for this purpose traverses are usually placed between every two guns; and as these masses serve to protect the men from the splinters of the bursting shells, they are generally called *splinter-proof traverses.* To make these entirely of earth would require a greater space in the batteries than could be given, they are therefore reveted with sand-bags, &c., or made by a double line of gabions enclosing a few feet of earth, as *a b* fig 108, crowned by a single line *c;* but if this be found insufficient, the lower tier may consist of three, and the upper tier, of two rows of gabions. In the memoranda of Sir John Jones quoted in the last paragraph, he says "between every two guns, a splinter-proof traverse of sand-bags was built up: it was made perpendicular to the parapet, 10 feet long and 1 foot distant from it at the base, and consequently its height, being regulated by the space between the platforms, so as to insure a thickness of 2 feet at the top of the traverse. To have ample room for these traverses, it is best to place the first two guns 18 feet from the epaulement; then leave a space of 22 feet, then 18 feet, and so on alternately, placing the traverse in the larger interval. These traverses in the batteries were of essential service, saving many lives, particularly at Rodrigo, where the number of shells thrown into the batteries was surprisingly great.'' In the defence of a fortress, 500 sand-bags are allowed for each piece of ordnance to aid in the construction of splinter-proof traverses, repairing embrasures, forming loop-holes for riflemen, &c.

262. Fig. 109 shows this construction: the first gun *a* is at 18 feet from the epaulement *o;* the second *b* is 18 feet from *a;* the third gun *d* is at 22 feet from *b*, and in this interval is the splinter-proof traverse *e;* and so on; so that the length of the

parapet from epaulement *o* to epaulement *p* will depend upon the number of guns and traverses to be placed behind it: the traverses are not always disengaged as *e*, but are sometimes connected, or engaged, to the parapet, as *g*.

263. Fig. 106 shows the dimensions that should be given to the profile of a battery exposed to a heavy fire: and, if it has to be constructed within the range of musketry, it becomes necessary, for the security of the workmen, to begin by placing a row of gabions *k* along the front of the ditch, and to fill them immediately, so that the men proceed with the excavation behind this cover.

Should the battery be at more than 600 yards from the place, the dimensions shown in fig. 106 may be a little reduced especially if the soil be stiff. The depth of the ditch should never exceed six feet in offensive works of this nature; as any thing beyond this makes it very difficult to throw the soil up from the bottom of the excavation: indeed a less depth (5 feet) is more convenient; in which case, as well as for the additional earth required for the traverses, the breadth of ditch, given in fig. 106, must be considerably increased.

The profile of a battery requires to be either increased or diminished, in the cases of its being commanded by the hostile work; or, the latter being commanded by it.

264. *Howitzer batteries* have usually the neck of their embrasures a little wider than long-gun batteries: although the new howitzers are so much lengthened in their bore that this wide opening will no longer be necessary, for they can be run out into the embrasure like long guns.

All short guns in batteries, such as the old howitzers and carronades, have the disadvantage of requiring wide necks for their embrasures, and thereby exposing the gunners. The flash, and expansion of the elastic fluid, on the explosion of the charge, also taking place at the neck, soon ruins the embrasure. Howitzers being fired with a little elevation, as well as guns for ricochet, the soles of the embrasures may in these cases be made with a counterslope, as seen in fig. 105, which adds something to the general stability of the mass. Howitzers and ricochet batteries may be made without embrasures to cover the gunners better, the guns at fifteen feet apart, and retired from the parapet so as to fire over it. A trench may be dug between the parapet and the guns, extending on both sides of the battery, in order to check the enemy's sorties. When howitzers are fired at considerable elevations, that is, 10° or 12°, this construction is best, and gives great strength to the parapet, which can then be countersloping at top, unless a fire of musketry is likely to be required from it, in which case, the superior slope must have the usual depression to the front.

265. Mortar batteries, having no embrasures, require their ditches to be greater than gun batteries, to furnish a sufficient quantity of earth for their parapets; and if exposed to a heavy fire their superior slope may have a counterslope, (as in fig. 107, *a b c*), which is a stronger profile than the usual construction with a dip to the front.

Mortars are usually placed at fifteen feet apart, and when fired at 45° of elevation, they are removed to a distance of twelve feet from the epaulement: as the angle of elevation is decreased, the pieces are proportionally removed to a greater distance from the epaulement.

266. *Platforms* for mortars and battering guns are absolutely necessary, if the pieces are to fire much from the same position, (as in batteries), unless the ground be rocky; else the soil would be so cut up by the wheels, that the fire could not be depended upon. Platforms for siege ordnance are therefore always carried by the train, commonly on carts or waggons, consequently lightness and compactness in their construction should be studied, as far as is consistent with stability and strength.

The platforms formerly in use were found inconveniently heavy during the Peninsular war, and their shape (being broader in rear than in front) very awkward to lay in the dark:

they were first reduced from their original size to fifteen feet in length, eight feet broad in front, and twelve feet in the rear, laid upon five sleepers, six inches by five, and covered with fir planks two inches in thickness; this reduced their weight from thirty-four to about seventeen hundred weight: still the planks forming the flooring of the platform being of different sizes, confusion arises in laying them down at night, and the different platforms are apt to get mixed. Sir John Jones in the same memoranda as quoted in the preceding paragraphs, says, "That after several experiments made at Woolwich, it has recently been decided, that an oblong platform, ten feet in width by seventeen feet in length, having five sleepers, six inches by five, which weighs only seventeen hundred weight, is every way suited for batteries to breach or enfilade*. If this prove so, it will simplify laying down platforms exceedingly, as then every plank will be available for every platform. It will, however, require the utmost circumspection and accuracy in marking the exact line of fire before dark. Four carpenters, working with ordinary exertion, unloaded a platform of the latter dimensions from a waggon, and laid it down in readiness to receive the gun in two hours; and the same men took it up and reloaded it on the waggon in one hour."

In laying the platforms, the sleepers are embedded in the earth, and lower in front than in rear, so that the flooring rises about nine inches in its whole length. It is recommended to screw the flooring or planks to the sleepers, as not only a firmer and less injurious proceeding to the timber, but as being less noisy—a matter of some importance in preparing batteries during the night, in the vicinity of the place to be attacked.

Mortar platforms are laid with great care, so as to be perfectly horizontal; for much of the correctness of the practice depends upon it. They should also be very strong to bear the recoil of the pieces, which acts more vertically and more severely upon them than the lighter horizontal recoil of guns, on their wheel carriages. The dimensions of mortar platforms are as follows:—three sleepers of ten feet in length, eight inches square; the planks are six and a half feet long, eleven inches broad, and three inches thick*.

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* "Perhaps, on further trial, fifteen feet may be deemed sufficient length, and nine feet sufficient breadth, which will still further reduce the weight."

267. *Field powder magazines.*—In the memoranda by Sir John Jones already quoted there is the following remark on this subject: "Splinter proof timbers for magazines were cut twelve feet in length, and from eight to ten inches in breadth and thickness, and were placed against an epaulement, parallel to the place, at an angle, making the base equal to half the height. They were then covered with a tarpaulin, extending well over the top of the epaulement, over which were laid one or two rows of filled sand bags, so as to prevent the possibility of the tarpaulin being cut by splinters of shells. A second tarpaulin was usually thrown over the exterior in rainy weather. On this construction the magazines were found to be perfectly dry, and sufficiently spacious, and of the strength no doubt can remain, as the sand-bag covering was frequently knocked off by large shells, and in no instance were the splinter proofs broken.

"The best situations for magazines are on the flanks of the batteries. Nothing can be worse than to place them in rear of the centre of a battery, as then every cartridge has to be carried along the most exposed and dangerous part of the battery, and the number of accidents and casualties which arise therefrom is very great indeed. The artillery always preferred to have two magazines formed, rather than to have one exceeding ten or twelve feet in length: when two were made, they were placed one on either flank. A situation, which was found to answer extremely well for the magazines of batteries constructed in advance of a parallel, was, at the extremity of a cut, made perpendicularly through the parapet of the communication from the parallel, at ten or twelve yards before arriving at the battery. The level of the floor of the magazine was then kept as nearly on the level of the approach as would admit of its being drained: and the foot of the splinter-proof timber was sunk twelve or fourteen inches under it. In this situation an accidental explosion of the magazine will not injure the battery."

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* The Addiscombe pupil is referred to the "Repository Exercise compiled for the use of the Madras Artillery," by Lieutenant Colonel Frith, Director of the Artillery Depot; copies of which he has been so good as to furnish for the use of the military seminary, and in which will be found detailed information of the platforms used in India.

268. It is customary to cover the flanks of batteries by epaulements as *o*, *p*, fig. 109; and, as these masses of earth are not in general exposed to so direct a fire as the parapet, they are not made so thick, nor is it necessary to revet their interior slopes: it is these epaulements that Sir John Jones refers to, in the remarks quoted at the end of the last paragraph, as the most suitable situations for magazines.

269. *To trace and construct a battery.* Let fig. 109 be a plan of a six gun elevated battery, which must be carefully executed on paper before it is laid down on the ground: the length of the crest of the parapet is determined for six guns and two traverses in the manner specified in paragraph 261: the profile is supposed to be of the dimensions shown in fig. 106.

1st. Trace out the length of the line *r r* for the base of the interior slope of the parapet with a cord or tape, then deeply and quickly score it with pickaxes and spades: lay off eighteen feet from *r* to *a*; eighteen feet from *a* to *b*; twenty-two feet from *b* to *d*, and so on; and mark the centres of the necks of the embrasures at these points, by driving down a strong picket at each: these pickets must stand as high out of the ground as the height of the soles of the embrasures are intended to be: (this will depend upon the nature of the gun carriage upon which the gun is mounted; for guns on travelling carriages are usually half a foot higher than on garrison or ship carriages), picket the lines *r q* perpendicularly to the crest of the parapet, and on the parts *r t* set up rough lath profiles of the required dimensions, (of the shape shown in fig. 110; having a cross piece *k l* to show the slope of the soles of the embrasures): the lines *s s* and *q q*, fig. 109, are traced and picketed, to shew the bottom lines of the scarp and counterscarp: these lines are respectively produced right and left as far as *x* and *y*, to picket the points where the bottom of the ditches of the epaulements meet that of the parapet: *r f* is measured perpendicularly to the rear, and *f h* also at right angles to *r f*: these lines are made equal to the distances measured on the plan, so that the epaulement *h r* forms an angle of about 120° with the parapet: rough lath profiles are set up perpendicularly to the epaulement at *h n*: these extremities need not be revêted: nor indeed is it at all necessary to rêvet the interior slopes of the epaulements: these masses *o* and *p* must be long enough to cover completely the interior of the battery.

2d. The ground is now ready for the working party, which is told off into squads and marched separately to their ground, where they receive directions to begin their work by excavating straight down on the lines *s s*, *q q*, the slopes to be formed afterwards; the soil to be thrown on the parapet except such portions as are wheeled off in barrows to fill the gabions, &c., that form the splinter proof traverses.

3d. While the excavation goes on, the traverses are traced and carefully built up in conjunction with the parapet: and the revêtement for the interior slope of the parapet is laid by the non-commissioned officers or the most intelligent men.

4th. When the mass is as high as the soles of the embrasures, the diggers and shovellers are directed to throw the earth towards the centres of the merlons, while the embrasures are traced; the lining of their cheeks and necks is arranged, and in proportion as this advances, the earth is well rammed against it.

In tracing the embrasures a ten feet rod is necessary; see fig. 109, embrasure *a*; where the ten feet rod is laid along the line of fire from the neck, and at its extremity two feet four inches is measured on each side, to get the play or opening.

270. With respect to the number of men required and their distribution, about one non-commissioned and fourteen men are necessary for each gun: for example, in fig. 109, for the portion of work at the gun *d*; (the marks *oo* show the distribution of the workmen).

4 Diggers in the ditch, to throw to
4 Shovellers on the berm, to throw to, and to arrange for,
4 Rammers on the parapet.
2 Builders
1 Non-commissioned } for the interior slope and the cheeks of the embrasures.

1 N. C. and 14 men.

Tools.

1 Ten feet rod
1 Bundle of pickets
1 Stake per gun
2 Mallets
1 Line of whipcord or tape
1 Mason's level
Profiles of lath } For tracing.
8 Shovels.
8 Pickaxes.
4 Rammers (to consolidate the earth).
2 Saws for fascines.

271. In calculating the time occupied in the construction of a field-work; first, compute the number of cubic feet to be excavated; thus, multiply the mean breadth of the ditch by the depth, for the number of square feet in the profile: this product multiplied by the distance between the workmen, in feet, will give the number of cubic feet which each man has to excavate and cast up. Now in common soils, it is known that a man can excavate about one hundred and thirty-five cubic feet in twelve

hours;* then if the quantity which each man has to excavate be multiplied by twelve and divided by one hundred and thirty-five, the result will be the number of hours required to raise the work; that is, under the supposition that all hands work equally: for example, take that portion of eighteen feet of the battery, in fig. 109, before the gun *d*, alluded to in the last paragraph; (the profile of the ditch is seen in fig. 106).

18 feet ÷ amongst 4 workmen = 4½ each
13 feet breadth at bottom
22 ditto ditto at top
35 ÷ 2 × 6 feet the depth = 105 feet × 4½ = 472½ cubic feet, the quantity each man has to excavate.
472½ ÷ 135 × 12 = 28⅓ hours; the period required to construct the battery represented in fig. 109.

This time may be abridged in the construction of such a massive work as is represented in fig. 109, by an additional row of men in the ditch, and by a supply of wheelbarrows and strong planks to form slopes or runs for them to wheel the soil up quickly. But on actual service when exposed to the hostile fire, all such calculations as the above must depend on circumstances.

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* For excavating soil for foundations, &c. in the south of England, labourers are now paid at the rate of 4*d.*, 6*d.*, or 8*d.* per cart load, according to the nature of the soil; the cart load is averaged at one cubic yard or twenty-seven cubic feet; in medium soil, a man can load five carts in a day of twelve hours (that is, he can earn 2*s.* 6*d.*): this will give one hundred and thirty-five cubic feet as the amount excavated and thrown up. In elementary works on fortification, it is usual to estimate a man's work for twelve hours at two hundred cubic feet, which can be done in soils easy to work in; but it is presumed that the foregoing statement will be found nearer the truth.

In the execution of field works, the workmen that have to excavate are assisted by others to remove the soil, as well as that they are relieved by fresh hands at proper intervals; consequently, the amount of their daily work may be fairly estimated as equal to that of a good day labourer. Task work should always be set, and no relief permitted till it be fully completed.

At page 201. vol. ii. Sir John Jones says "The time necessary for throwing up batteries cannot but be affected by the circumstances under which they are formed, the fire to which they are exposed, the nature of the soil and the materials at command; and must vary at every operation.

"Thus the Prussians in summer (after the battle of Waterloo in 1815) erected batteries in twelve or fourteen hours against places almost destitute of gunners; and four days were found necessary for their erection during the frost of January, and under the powerful and well directed artillery of Ciudad Rodrigo." (December, 1811, and January, 1812).*

272. The covered-road spoken of in paragraph 251, is the next subject for consideration: its progress may be seen in fig. 113; where the three district periods alluded to, are marked by the trenches *a*, *b*, *c*, that run parallel to the general outline of the place, and hence their name *parallels*.† (The place being fully invested and the fronts to be attacked fixed upon). At the time appointed the working parties move to their allotted stations in order *to break ground* or open the first parallel at a distance of six hundred yards from the salients of the covered-way of the place. This distance is previously fixed by the engineers, and all prepared before night-fall to commence operations; after dusk the working parties move silently to their posts, and lie down till the appointed signal is given to commence the excavation; they are protected in front by an armed covering party *d*, having detached pickets *e*, and chains of sentries *f f*, as seen in fig. 113; to repel any sortie which the garrison may attempt to make, in

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* The Addiscombe pupil is referred for information on the time occupied in constructing the field works in the grounds of the seminary to "The Record Book of Field Works executed by the Gentlemen Cadets."

† It does not however follow that these trenches are always made parallel to the general outline of the works attacked It often happens that local circumstances favour their being constructed in a different direction.

order to interrupt the work. Every endeavour is made previously to breaking ground, to deceive the garrison as to the fronts they selected for attack, by making a reconnoisance on all sides, and apparent preparations for opening the trenches; the besieging corps furnishes both the covering party and the workmen; all of whom are paraded in proper time by day light, and told off for their respective duties. The experience gained in the sieges under the Duke of Wellington led to the following arrangements, detailed by Sir John Jones in his "Memoranda relating to the Manner of Carrying on the Duty and Performing the Work at the Sieges in Spain." Vol 2, page 179.

"*Breaking Ground.*

"A certain number of brigades of engineers were ordered for duty, and the working party being told off into a similar number of divisions, the tools were laid out in separate portions in the park, according to the strength of the several divisions of workmen. As soon as it became dusk, the commanding engineer, having previously well reconnoitred the ground, went with the officers of engineers for duty, attended by a few of their overseers, and pointed out to them the line of the parallel and the returns of the approaches to it. The officers then divided the extent of the work between them, beginning at one end of the parallel, according to seniority; and each taking for his portion of it a certain number of yards, according to the number of men contained in his division of workmen. He then planted a picket at each end of his portion of work, and ran a white line from one end to the other; and that the pickets might be readily found when it became quite dark, he made one of his overseers lie down at each; and in like manner were all the returns of the approaches marked out. Whilst this was executing, the sub-officer of each brigade, after having well remarked the situation of his portion of the work, so as to be certain of finding it in the dark, returned to the place of assembly of the working party, and took charge of his division. The whole were then marched in one body to the place of breaking ground, either to the centre, right, or left of the intended parallel, as the country offered most facility for advancing. When that happened to be in the centre, the workmen were filed in two parties to the right and left; but, to avoid confusion, they were, whenever practicable, filed along the whole length of the parallel, say from left to right. Then the officer with the leading section marched on till he arrived at the picket on the extreme right; the second officer halted his division when the head of it arrived at the right picket of his brigade; the third officer halted his at the right picket of the third brigade; and so on with the other divisions. Without this precaution of halting each division separately, as the men march in much closer order than they work, they would all be crowded together, and in the dark it is almost impossible to make men extend themselves into regular distances. Each man on marching out of the park carried a fascine four feet in length, which, on the division halting, he placed down parallel to the white line, at two feet in front of it; and as he afterwards only opened the ground to the white line, and threw the earth beyond the fascine, a space of two feet was left for the banquette.

"The workmen were placed four feet apart, and were expected at that distance to complete before the hour of being relieved, a trench three feet in depth by three feet six inches wide at bottom, being something more than a cubic yard and a half of excavation. Frequently, however, they did not complete the allotted excavation; which could only arise from want of due exertion, for under a heavy fire they never failed to perform the same quantity of work in three hours. It would, therefore, be a desirable regulation to enforce, that, on breaking ground, no relief should take place till an assigned portion of work had been completed. The workmen under the present system of relieving them at a fixed hour, whether they have done much or little, feel assured that they shall quit the trenches before daylight, and are not interested that proper cover should be obtained against the fire of the place, which seldom opens with much effect till that period.

“ This regulation for a fixed quantity of labour being performed by each relief might be beneficially extended beyond the night of opening fresh ground ; and, perhaps, even a system of task-work might be introduced generally for the works of an attack, it being invariably found that the men laboured with the utmost ardour and cheerfulness through five or six hours to obtain a remission of the remainder of their period of duty in the trenches.*

“With each division of workmen a number of spare tools should be sent, as it will unavoidably happen that in some parts of the line four or five men will be found working together with the same nature of tool ; also in some parts the ground will prove soft and require shovels only, and in some parts so hard as only to be moved with pickaxes. To attempt to change the men or tools in the dark is productive of endless confusion ; so that where the supply of tools will admit of, each man should carry a shovel and a pickaxe.

“ * The following order is inserted to show that a system of making troops labour by task-work received the sanction of, or rather emanated from, the Duke of Wellington.

MEMORANDUM, *April 9th*, 1812.

“ Colonel Fletcher is requested to order an engineer officer at Badajos, to assist Major General Power in getting the ladders out of the ditches, &c. and collecting them ; in placing the chevaux-de-frize upon the breaches so as to prevent all ingress and egress by them ; and in shutting the barriers of the covered way, outworks, &c.

“ An engineer officer to be appointed to superintend the rubbing out of the trenches ; Colonel Fletcher to call upon General Power to supply him with a working party of 500 men at twelve this day for that purpose ; this same number to be supplied to-morrow at five in the morning, to be relieved by the same number at twelve, and to continue in this manner till the work will be finished.

“ This work should be tasked, and the men kept at work till they will have finished their task”.

"At the distance of the first parallel, or 600 yards from the covered-way, there is in high latitudes a considerable period of partial obscurity, during which the work may be seen to be traced, those so employed not being observable from the garrison; but in southern latitudes the day is so immediately succeeded by darkness that not a moment is to be lost in fixing the different points. After complete darkness it is impossible to trace any line with certainty, for even the very bearing of the front to be attacked becomes doubtful; and on such occasions if a man be not left lying down at the different points, or a white line used, the trace may remain undiscovered for the whole night.

"To enable the engineers to trace out the work in the dusk with security to themselves, it is desirable that the investing corps should, at sunset every evening, close upon the place, and that it should, even in the day time, hold all such advanced posts as it can without loss of men. During the time of fixing the marks in the dusk, sentinels must be advanced in front of the officers so employed, and a strong support be posted near at hand, or a cavalry patrol might sweep the whole party into the place.

"Reconnoissances of other points of the fortress should be made daily during the investment, and more particularly of those parts of which the garrison show a jealousy by much firing. It will frequently serve to prevent suspicion of the intended point of attack. At Badajoz, both in 1811 and 1812, officers were employed with much show to reconnoitre the south fronts, whose motions were jealously watched and interrupted by fire, men being even sent out of the place to occupy some ruins to prevent their near approach on that side; whilst underneath the castle the commanding engineer, attended by another officer, was actually pacing the intended parallel uninterruptedly, under the show of being officers regulating the advanced sentries. At one point this was done close to a French picket, which, by a sort of tacit agreement, quietly occupied in the day time a house beyond the glacis, retiring from it every evening on the advance of the investing pickets, neither party ever firing on the other.

" *Covering Parties.*

"The covering party preceded the working party, and was conducted by an officer of engineers, selected for that purpose from those who had accompanied the commanding engineer when he laid out the parallel in the dusk; and who, having made himself thoroughly acquainted with the roads, had returned to the place of assembly of the troops, which was usually at the engineers' park. In these sieges the covering party was always placed a few yards in front of the workmen; but of course the general officers of the day places it wherever he thinks proper, either in front or rear of them. It would, however, seem most advisable to place it in front, as the natural weapon of the British, and the most effectual in the dark, is the bayonet, and the order of the troops must necessarily be destroyed in crossing over the work and through the workman to use it. Again, the covering party being in front of the workmen gives them a confidence, which is essentially necessary to their attending to the work. For the same reason it is better that the workmen should have their arms, for, when without them, they disperse on the slightest alarm, and it is very difficult to collect them again; but such is the natural intrepidity of the English soldier, that, with his arms, he never thinks of moving off. The workmen carrying their arms, is admitted to be a great impediment to the work in many respects, but that is considered as being much overbalanced by the confidence it inspires amongst them and the real security it affords.

"The battalions, as soon as posted, were made to lye down, having small platoons of men placed in their front, with advanced sentinels. The sentinels had positive orders not to fire on any account, and the squads were not to fire unless assured of a sortie advancing in force."

Besides the working party to execute the first parallel on the night of breaking ground, a detail is also told off to connect the parallel to the depôts in the rear, by means of trenches of communication, *g g*, fig. 113, a profile of which is seen in fig. 114. Good epaulements, *h h*, fig. 113, should also be prepared behind the extremities of the first parallel, for the protection of cavalry, who may be required to act against sorties.

The distance of six hundred yards is selected as suitable for the first parallel, as here there is little to fear from musketry, grape, or canister; but when the localities of the ground require that any portion of the parallel should be advanced or retired, in order to command the ground in front, it should be done.

The moment that the parallel affords cover, as well as room, for the workmen to continue their excavation, the main body of the covering party retire into it, leaving their picquets, or sentinels, in advance; but all are to be under cover by daylight next morning.

The parallel is widened and completed during the day after breaking ground, affording a covered post of the dimensions shown in fig. 115.

The parallel is intended as a place of arms, furnished with a guard to protect the further approaches against the efforts the garrison may make to retard or destroy them. Sir John Jones remarks, in the memoranda already quoted, that—

"The guard of the trenches most usually relieved at noon, or as soon as the men had dined, and remained on duty twenty-four hours. It would probably be better not to send the guard into the trenches on the first day after breaking ground, as there is seldom sufficient cover for them and the workmen also; and the trenches being still more than 500 yards from the place, and literally not worth destroying, whilst their distance takes away all chance of surprising the workmen, the garrison are not likely to make any vigorous sortie. Therefore, a few steady men being placed in the parallel, the remainder of the guard might till evening be kept under the nearest cover, in readiness to advance if required. Such an arrangement would save casualties and give room for the workmen to exert themselves.

"Some valuable assistance was obtained on more than one occasion in forwarding the work by a portion of the guard aiding the working party. As exercise is beneficial to the men in cold and damp weather, this aid should be freely asked by the engineer, and willingly granted by the officer commanding in the trenches, when it can be done with safety."

"The guard of the trenches generally at these sieges, but more particularly at this attack, fired much too rapidly, and too indiscriminately at all points of the defences; and the consequence was, an excessive expenditure of musket ammunition.

"It is so natural for troops to fire before them without consideration, that the musketry of the guard of the trenches can only be rendered effectual through the utmost attention and vigilance on the part of the officers. They should select out the best shots, and see that they are well covered with sand-bags, placed on the top of the parapet, with an opening between them, just sufficient for their musket barrels, and should explain to the men the object of their being so posted, and caution them only to fire when a probable chance of success should present itself. The remainder of the guard should be kept seated on the banquette under cover, in readiness to receive and repel sorties. Any general fire of the guard of the trenches cannot be otherwise than wasteful and ineffectual.

"The French certainly at this siege acted most strictly on these principles, for the men of their firing parties were invariably posted behind good cover, and never for a moment exposed themselves to view; and they must have been selected marksmen, for every gabion placed by the full sap was pierced by at least twenty bullets, although apparently the fire on the head of the sap was not very great.

" *Parallels and approaches.*

" The first parallel was made ten feet in width clear of the banquette, which is more than absolutely necessary. Against a weak garrison seven feet will usually be found sufficient; but when of that dimension, if the country be such that carriages cannot cross over it, but obliges them to move along the parallel, the precaution must be taken to make various portions of the parallel sufficiently wide to admit of two carriages passing each other, or occasional stoppages will occur to interrupt the communication for hours.

" Parallels are, strictly speaking, merely defensive lines to repel sorties; therefore, the chief object to be attended to in forming parallels and approaches is a convenient arrangement of the troops for engaging, and a ready communication for support between every part of the trenches. The parapet is little more than a screen, nor is it possible to render it shot-proof for a foot or two below its crest; neither is it materially important, provided it screens from view every thing passing behind it, for no besieged place can afford to risk the loss of its ammunition, by maintaining much fire on any part of the approaches, which they cannot positively ascertain to be thickly occupied with men. Good banquettes in all the parallels are essentially necessary, and the second parallel, and every part of the work in front of it, require to be revêted with gabions, fascines, or sand-bags, as otherwise the men firing from the banquettes, are not sufficiently covered from the effects of grape shot.

" It is, however, very desirable in all interior revêtements of parallels, or places of arms, more than 150 yards distant from a place, to make the revêtements in steps, so as to offer a ready means for the guard of the trenches to advance on a good front, and meet or pursue a sortie with their bayonets. When the approaches are very near, to obtain good cover from musketry and vertical fire is more essential than facility of egress.

"At the siege of the citadel of Antwerp, in the winter of 1832, owing to the tempestuous state of the weather and other causes, it was not until near midnight that the working parties were definitively posted, and enabled to commence breaking ground; but as the nature of the soil rendered the employment of the pickaxe almost unnecessary, the works advanced rapidly, and the whole of the troops were under cover by day-light. The mere insertion of the spade beyond the depth of eighteen or twenty inches infallibly produces water; this was of course attended with many serious evils, and in some parts rendered the trenches untenable, and utterly prevented the possibility of conveying artillery through the ordinary channels; at the same time, this was attended with two marked advantages: as the absence of all stones and hard substances not only afforded greater facility for rapid excavation, but had the important merit of diminishing the danger of splinters; whilst in many instances the heavy shells embedded themselves to such a depth as to render their explosion perfectly innocuous. Thus, out of twenty-eight of these projectiles thrown by the besieged, during one day, into battery No. 7, three only cast their splinters above ground.

"At this siege the nearest point of the first parallel was only three hundred and twenty-five yards, and its furthest point four hundred and fifty yards, from the most advanced works of the citadel: the length of the parallel was one thousand and seventy yards, and the approaches from the rear three thousand seven hundred and fifty yards."—*United Service Journal, No.* 52.

273. On the morning after breaking ground, the engineers determine the positions in the parallel for the construction of the batteries to be raised to subdue the fire of the place: the situations for the ricochet and enfilade batteries are fixed at the spots where the prolongations of the faces of the various works (that command the ground to be passed over) fall into the first parallel; and those for direct fire are opposite to the faces to be counter-battered.

Fig. 122 shows the outline of part of an attack made upon the front *e* of a hexagon; the two adjoining fronts being included within the envelopment of the first parallel, that batteries may be erected to silence their fire, which commands the ground of attack: the object is to gain possession of the ravelin *n*, and to penetrate the enceinte by either of the bastions *o* or *r*.

Batteries Nos. 1, 2, 3, 4, 5, 6, 7, 8, and 9, are erected to *enfilade* the faces of the works, whose prolongations, (it may be observed by the figure), fall into them: but as the faces of the extreme bastions, *c* and *d*, when prolonged, fall upon ground quite beyond the reach of the first parallel, the batteries *a* and *b* are armed to combat them by a *direct fire*. The batteries 3 and 7 need not be constructed, unless the fire of the faces of the ravelins, *i* and *k*, become troublesome; for these faces see only a portion of the ground of attack, and that obliquely.

In the second volume of his Sieges, at page 200, Sir John Jones observes, that "The best situation for batteries is in the parallel, as, by placing them there, their position may be determined at day-light of the morning, after breaking ground, and fourteen hours will thereby be gained, besides profiting by the excavation of the night. The terre-plein of the batteries in this case will be sunk three feet; which should be made the level of the *bottom* of the sleepers of the platforms, as an excavation exceeding that depth retards the completion of the battery, from the disproportionate quantity of soil it gives to that required for the parapet, which it is unnecessary to make of a greater thickness at top than ten or twelve feet, or at the utmost fourteen feet. Batteries of this construction and profile may readily be completed to open in thirty-six hours, numbered from day-light of the morning after breaking ground.

"Batteries to breach, or for direct fire, cannot frequently be sunk, and the ditch alone affords the mass of earth for the parapet; when such batteries are within effectual musketry range of the place, it is expedient to plant a row of gabions along the front of the ditch, and to fill them instantly upon commencing the excavation. Such a precaution will save many casualties among the workmen.

Hence it would appear, that batteries *a* and *b*, in fig. 122, being for direct fire, should be elevated; while the remainder being for enfilade and ricochet fire, may be sunk, and can be constructed in the parallel, in which case, there should always be a trench of communication round their rear connecting the parallel, that the service of the battery may not be interrupted.

The pupil is referred to the supplementary notes, paragraphs 301, 302, 303, and 304, for information on the number of men, the quantity of artillery, of ammunition, and the engineer's means, necessary to carry on a siege with vigour.

It is of the utmost consequence to complete the batteries on the first parallel as soon as possible, that the fire of the defences may be checked and subdued by the combined efforts of the enfilade, ricochet, direct and vertical fires, of the besiegers' batteries. The pupil is referred to paragraph 302 for information as to the quantity of artillery required for the arming of these batteries.

274. While the arming and practice of the batteries is going on, the engineers prepare for pushing the trenches towards the place. These are constructed in a zigzag direction; so that, when prolonged, they shall fall clearly without all the defensive works, that they may not be enfiladed. These trenches cross the capitals of the ravelins and bastions alternately to the right and left. Here they are not exposed to the direct fire of the works, towards which they advance; and also, it may be observed, (by examining the directions of the fires from the various batteries on the first parallel in fig. 122,) that the zigzags, *z z*, are in situations where they interfere less with the fire of the batteries than if constructed anywhere else.

In distributing the men for excavating the zigzags, they are placed as seen at *o o o* and *x x x*, fig. 116, that the return *a b c* may be executed at the same time as the rest; so that the men filing along the trench *e* into *g* may be covered in front as well as on the right flank, whence comes the fire of the place: the extremity *z* of the zigzag is formed into a ramp, to facilitate egress and ingress. The zigzags to the rear of the first parallel are, in like manner, directed clear of enfilade, and have protecting returns to cover their openings.

As the zigzag trenches are merely intended as covered communications from one parallel to another, they are not furnished with a banquette; and, as they only present their parapets obliquely to the fire of the place, there is no necessity for a greater thickness than twelve feet to the whole parapet at the base, as seen in fig. 114.

The zigzags are pushed on till they arrive nearly within the reach of the musketry fire of the place, or within three hundred yards of the salients of the covered way; but they are never constructed beyond the efficient range of the musketry of the place of arms, or parallel in their rear, that has to support them.

One of the errors of the old method of attacking fortresses was, that of establishing the first parallel as just described, and pushing on the zigzags to the foot of the glacis, unsupported by parallels, in consequence of which the sorties from the place had only to act against the guard and workmen that occupied the head of each approach, and were therefore generally successful in destroying the work, and greatly retarding its progress.

Vauban first introduced the enveloping parallels; the second within musketry range of the first; and the third and fourth between the second and the glacis; so as always to afford the approaches not only a good close fire, but a strong guard at hand, to repel any attempt made to interrupt the work by sorties.

When arrived within the range of the musketry of the place it becomes necessary to construct the trenches with greater care and caution, and as the mode of doing so is called sapping, an explanation of the process is requisite.

275. *Sapping* is a mode of constructing trenches and parapets under a musketry fire. The sappers, or engineer soldiers, must be well instructed in their business; it is a slow operation, as the work cannot proceed at a quicker rate than what one man can dig at a time. For this duty, the sappers are told off into squads or brigades of four men each; the man at the head of the squad is the first sapper, and they are numbered 1, 2, 3, 4. The head of the trench, which they dig, is covered by a sap roller (paragraph 253 and fig. 104): and, on the flank whence the fire comes, the sappers are protected by a line of gabions filled with earth. Figs. 117 and 118, show a plan and section of a single sap, with the work of each sapper numbered: the sap roller *c* is pushed on by the head sapper, assisted by No. 2, by means of forks having long handles. The first sapper cuts the trench marked No. 1, making it eighteen inches wide and eighteen inches deep: No. 1, also places each successive gabion: he works on his knees taking care to leave a berm or banquette of eighteen inches between his trench and the row of gabions: he works in a length of five feet, with which the following sapper does not interfere: No. 1 is very careful not to allow his body to pass the gabion last placed till he has filled it with earth, and placed a sap-fascine or a couple of sand-bags in the hollow between the two advanced gabions, so as to have a musket shot proof cover behind which to continue his work: the leading sapper thus occupies the most dangerous, as well as the most laborious post, which each of the squad takes in succession.

No. 2 works on his knees and excavates the trench marked 2 in the plan and section; to equalize the work, his trench is twenty inches wide and eighteen inches deep, having a length of five feet.

No. 3 follows No. 2, deepening the trench to three feet: and No. 4 completes the trench by enlarging its breadth ten inches and deepening it to three feet: the earth excavated by the squad is first put into the gabions and afterwards thrown beyond them, so as to form the rough parapet seen in the plan and section.

Working parties follow the sappers and complete the trench to any dimensions that may be required.

In sapping or in using gabions as a revêtement, &c. they should always have a little slope outwards towards the parapet, of about one quarter their height; for if placed quite upright, any swelling of the fresh earth of the parapet from rain, would throw them down inwards.

276. The time occupied in constructing ten feet of sap, in the manner just described, is about one hour; but if, during the night, the fire from the place slackens, portions of sap may be pushed on more rapidly by placing several gabions at a time and filling them simultaneously; when this is done, it is termed *the flying sap*. The French sappers at the late siege of the citadel of Antwerp, were armed with helmets and cuirasses according to the old system: these were found to resist musketry, but were insufficient against grape and splinters.

277. The execution of the second parallel is generally by the flying sap: its distance is within the extreme range of the musketry of the covered-way of the place, or three hundred yards.

The tracing of the first parallel requires considerable care; the true distances from the salients of the place must be fixed; and it must embrace all parts of the fortress that look upon the march of attack: in tracing the second parallel, guided by the plan of attack, points on the first parallel are marked at equal distances from each other; engineers start from these points walking upon some fixed objects till they have paced three hundred yards; they then connect their positions by white tapes picketed down.

The working parties assemble at the engineers' depôt before dusk, where their tools are arranged in columns, behind which the divisions file: each man carries a gabion and an entrenching tool: a spade and pickaxe between two, who afterwards work together behind their own pair of gabions; the working party is preceded by a covering party having an advanced chain of sentries; the whole supported by battalions in the most advanced zigzags or approaches: each engineer conducts his men (in the manner described in Sir John Jones's note, paragraph 272) and sees their gabions placed close together at two feet beyond the white tape: the men then lie down till the engineers have ascertained that the whole is connected and ready; when, at the appointed signal, the excavation begins: the gabions should be filled and musket shot proof in ten or twelve minutes, after which the earth excavated is thrown beyond the gabions to form the parapet; ample cover should be obtained by day light next morning as well as a respectable width of trench finished, as every two men have only the breadth of two gabions (about three feet four inches) to excavate.

Elementary writers give the fourth or fifth night from breaking ground as about the period for executing the second parallel.

The parapets of the second parallel, as well as those of all the other parallels nearer to the place, must have sufficient thickness to resist the fire of the artillery of the place: the first parallel from its great development, is a mere screen and covered post, nor would an enemy waste his ammunition by attempting to destroy it: it is true that he may concentrate his fire upon some particular suspected spot; but the general dimensions may on the whole, be even less than those shown in fig. 115. But were the enemy to concentrate his fire upon portions of the second parallel which is so much less than the first in its extent, and within 300 yards of his guns, the communication might be seriously interrupted; consequently the parapet must have a base of at least eighteen feet. On the night of constructing the second parallel, some zigzags of approach beyond it, may be traced and executed by the flying sap; but, from the proximity of the place few opportunities will afterwards present themselves for this expeditious mode of construction, unless the fire be very slack indeed.

At page 208, vol. 2, Sir John Jones says, that "At St. Sebastian, the sappers finding the fire from the place very slack, contrived to push on the approaches more rapidly than usual, by a mixed nature of flying and full sap: that is, the sappers advancing on their hands and knees, placed one empty gabion after another, till a small row was formed: then two or three sappers placed themselves behind the empty gabions at good distances from each other, and sitting at their work, each formed a small hole for himself, and with the earth from the excavation filled the gabion in his front; after this, the sappers severally worked towards each other, till the whole row of gabions was filled and a trench formed along their rear. This mode of proceeding would probably facilitate the reduction of a small detached work, the artillery and musketry of which was well kept under, but would not be generally found practicable under a smart fire."

278. The second parallel need not be of such an extent as the first: and it is customary to protect its extremities by forming redoubts, to contain a few pieces of light artillery and a strong detachment to repel sorties; these redoubts are recommended to be constructed as that seen in fig. 122, *g*; that all the faces prolonged may be clear of the works of the place, and not liable to be enfiladed: the rear faces of such redoubts, not being exposed to the fire of the place, need not be of so strong a profile as the front faces.

Instead of a redoubt, the extremity of the second parallel may be continued in a defiladed curve to the rear to join the first parallel, as *f* 87, (accented), fig. 122, which has the advantages of shutting in all the ground between the parallels, and of giving an additional trench of communication, which may prove of importance in reinforcing the troops in the second parallel, if attacked by a strong sortie.

If the defence be not very active, neither of these methods need be resorted to, but the extremities left *en l'air*, as *b b* fig. 113.

279. By reference to fig. 122, it may be seen that the fire from batteries No. 1 and 9, is not at all obscured by the second

parallel: and, if the ground between the first parallel and the place, be level, the second parallel will not interfere with the fire of the other richochet batteries: for the guns being fired with an elevation (paragraph 8) the second parallel will be nearly under the trajectory or highest part of the curve, described by the flight of the shot. But should the localities of the ground cause the second parallel to mask the fire from the batteries on the first, fresh batteries must be constructed in corresponding situations, and for corresponding purposes, on the second parallel; and the guns removed into them: for example, in fig. 122, the batteries with the accented numbers 2, 3, 4, 5, 6, 7, 8, on the second parallel, will supersede the like unaccented numbers on the first parallel; and, if necessary, the batteries *a*, *b*, for direct fire must also be removed to the second parallel, from which the practice will be much more powerful and correct.

Under all circumstances, the fire from the batteries must be unremitting and amply sufficient to keep under the fire of the defences; for all the trenches beyond the second parallel are formed by the sap, which cannot be conducted against the fire of artillery.

At the siege of the citadel of Antwerp in the winter of 1832, it became necessary to move the batteries from the first to the second parallel, on which the French general of Artillery Neigre observes, in his report, that "The disarming of the batteries in the first, and arming of those in the second parallel, was gradually performed, so as not to render sensible the diminution of fire during this operation; and that since the opening of the trenches on the night of the 19th of November, (to the 11th of December) nineteen batteries with platforms for 138 pieces, had been constructed." *United Service Journal, No.* 52.

280. As the approaches draw nearer the attacked place, it becomes more and more difficult to defilade the branches of the zigzags, especially if the fronts of the enemy's works be extensive, (or on a high polygon), without making the alternate

angles inconveniently acute. It then becomes necessary to advance in a straight line by the *double sap*, which, as its name implies, is two single saps, as seen in plan and section in figs. 119 and 120. Two squads or brigades of sappers are employed at a time, each covered in front by a sap roller or mantlet*, having a smaller one in rear of the centre of the two great ones; and they work in the manner represented in the figures. The great sap gabions are each six feet long, and as they are a few inches apart in the centre, the work will be well covered if the sappers have their respective rows of gabions twelve feet asunder.

If the sap be pushed on in a direct line for any length it becomes subject to be enfiladed, unless intersected by traverses, which must become numerous and substantial in proportion as the enemy's works are commanding and vigorous in their fire. Fig. 121 shows a simple and well covered method, which the compiler saw executed by the field engineer department under Colonel Pasley, at Chatham, some years ago, and of which he then took the dimensions. There are several other methods of executing the double sap with traverses, but that in fig. 121 is one of the most approved modes†.

Much more detailed information on sapping can be found in a pamphlet, published by order of the minister of war in France, in 1828, written by Captain Villeneuve, of the French Engineers, entitled, "*Manuel pratique du Sapeur.*"

281. The zigzag approaches, either by the flying or single sap, are pushed on from the second parallel, till they reach within one hundred and fifty yards of the crest of the glacis of the place: here it becomes necessary to establish *demi-parallels*,

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* A mantlet is a musket shot proof sheet of iron fixed to a frame, moveable upon small wheels or trucks, and pushed on before the leading sapper, instead of the sap roller.

† The two models of saps, in the model room of the seminary, show a different construction from fig. 121; the circular double sap with lock traverses is one, and is considered the most expeditious mode of performing the work.

or portions of parallels, to contain strong guards to protect the further progress of the work, and to answer the enemy's musketry, which is done through loop-holes formed by sand bags, or gabions, (paragraph 258). These demi-parallels are formed in a curve, extending so as to embrace the prolongations of the covered-way before the attacked works, see fig. 123, (*e e*, is the second parallel): the zigzags of approach are seen on the capitals *a b c:* the curves *dd* are the demi-parallels, at each extremity of which there is a battery of three eight-inch howitzers on the prolongations of the six branches of the covered-way; in order to enfilade and ricochet them, and to keep down their fire as much as possible, by tearing up their traverses and clearing their banquettes, these howitzer-batteries are sunk; that is, they are formed *in* the demi-parallels, that they may not mask the fire of the batteries in their rear.

282. From the demi-parallels the sap is continued on the three capitals as far as it can be carried in a zigzag direction; but when the zigzags become too multiplied, or nearly parallel to each other, in consequence of keeping them clear of enfilade, the double sap with lock traverses must be resorted to as seen at *f, f,* fig. 123; when the saps on the three capitals have reached the foot of the glacis, they break into simple saps and deploy to the right and left to connect their work together, to form the *third parallel,* as seen at *p, n, n, p,* fig. 123. In all this work the guard of the trenches must follow close upon the sappers, and that in the demi-parallels and second parallel must be prepared to meet sorties that may now reasonably be expected to destroy or retard the work so near to their covered-way. As soon as the third parallel is sufficiently advanced, a battery of four mortars is placed opposite to each of the re-entering places of arms (at *n n n n*, fig. 123), in order to shower into them grape of hand grenades, &c. alluded to in paragraph 303; so that, with the fire of the howitzers in the demi-parallels, and the batteries on the first parallel, the defenders may be quite overpowered.

The third parallel should have a greater capacity than the others, for it has not only less developement, but the quantity of materials to be collected in it, for further proceedings, is very great. A strong vigilant guard must fill the third parallel, and keep under the musketry fire of the place.

283. It now becomes necessary to seek for the defensive mines, for it will be needless and destructive to attempt to push on the sap, until the ground below has been secured; for the mining operations at a siege the pupil is referred to the subject as treated from paragraph 205 to 236, especially from paragraph 220 to 232.

The foot of the glacis being about eight feet beneath its crest, nineteen feet beneath the crest of the ravelin, and twenty-two feet below the crest of the enceinte, the third parallel will not mask the fire of the artillery behind it.

284. The next operation is the crowning of the covered-way, for the purpose of establishing breaching and counter-batteries. It is for the general commanding to decide upon whether this is to be done "*de vive force*," or by the more slow and safe mode of sapping. The motives that usually lead to the former are of a political nature, that render it essential to abridge the duration of the siege. If these motives should be pressing—if the feeble fire of the besieged announces his weakness and discouragement—if it be seen that his redoubts and retrenchments in his places of arms are silenced and dismantled,—the attack *by storm*, or "de vive force," may be adopted, and the lodgment or crowning of the covered-way made by the flying sap. But, if the besieged has redoubts and retrenchments in good order, in his places of arms—if there be good reason to suppose that the enemy can run up his remaining guns from behind protected traverses upon his barbettes, and shower canister and musketry upon the covered-way and glacis—and if, above all, it should be of little importance to hasten the fall of the place by one or two days, such an attempt should not be hazarded; which, if it does not succeed, will only retard the progress of the siege at a heavy

loss of valuable lives; and if it does succeed, it will be too dearly purchased by the sacrifice of many gallant soldiers.

285. *To attack the covered-way and to establish the lodgment "de vive force."* After the third parallel has been completed, a great quantity of materials, such as gabions, fascines, sand-bags, entrenching tools, &c., are to be arranged on the top of the reverse slope of the parallel. Good and numerous steps are made in the various parts of the parallel, by layers of fascines and hurdles well picketted down, so that the troops can move out by them in regularity: the parallel to be lined with riflemen, who, with all the batteries, keep up a heavy fire till the moment the troops issue from the parallel. The close of the day, while still dusk, is recommended as the most suitable time for the operation, as there is then sufficient light to prevent confusion, and the work has the benefit of the approaching obscurity. The storming party march directly upon the salient places of arms, and enter the covered-way by the openings previously made in the palisades by the enfilading batteries: some of the party, however, are armed with hatchets to force the barriers and palisades, should they not have been destroyed. The active fire of the batteries will have nearly cleared the covered-way of the defenders, and the storming party drive the remainder from their traverses, and keep possession of the covered-way, while the working party, that has closely followed, trace the lodgment by ranging their gabions parallel to the crest at eighteen feet, filling them quickly with the soil of the glacis excavated in their rear, and cover is obtained as rapidly as possible by the aid of sand bags, fascines, bales of cotton, hay, &c.: thus, in a hexagon, as in fig. 123, the crest of the glacis at the salient places of arms, before the two bastions and one ravelin, is crowned by the flying sap, to as great an extent as time and circumstances will allow, as *m*, *m*, *m*, fig. 123. Traverses *p* must be made to prevent the work being enfiladed; and part of the workmen must be told off to form a double flying sap, *o o*, with lock traverses to connect the lodgment

with the third parallel. The storming party retire into this lodgment as soon as it can give them cover.

286. If the attack has been successfully carried on, and the weather has been such as not to fill the trenches with water and to delay the work, it is customary to calculate upon completing the third parallel about the twelfth night after opening the trenches; and if the safe process of sapping regularly up to the crest of the glacis be followed, it may begin about the twelfth or the thirteenth night, by striking out single saps, *a a*, fig. 124, about thirty yards on each side of the capitals of two bastions and ravelin of attack, and carrying them forward in the curved direction therein shown, so as to meet about twenty yards up the slope of the glacis: these *circular portions* are defiladed from the fire of the place by their curved shape; and from them double and direct saps, with proper traverses, are carried forward, till they arrive within thirty yards of the angles of the places of arms: here the double brigade of sappers separate, one turning to the right and the other to the left, and describe a single sap round the salients of the covered-way, till each has reached the prolongation of one of its branches; the saps are then made perpendicular to these prolongations, and equal in length to the width of the covered-way, (viz. thirty feet) : they are terminated by a return defiladed from the works of the place, which serves as an epaulement; these spaces, *c*, *c*, fig. 125, are formed into *trench cavaliers*, *c d*, fig. 126, in order to obtain a command over the interior of the covered-way, to clear it of the enemy by a fire of musketry. Thirty yards from the crest of the glacis has been fixed upon for these cavaliers, as being a distance rather greater than men can throw hand-grenades.

The dip of the glacis at thirty yards from its crest may, in general, be reckoned about four feet; therefore, to obtain a command over its crest, the parapet of the trench cavalier must be raised at least five or six feet above the surface at these spots: the returns (*f f*, fig. 125) of the sap, must, in like manner, be elevated, to prevent the men being seen and taken in flank, by an enfilading fire; and, likewise, to furnish fire against the portions of the covered-way, and the faces of the adjoining works.

The cavalier of trench is finished as seen in fig. 126: the original sap consists of the dotted portion 1, 2, 3, 4, the gabion *g*, and the parapet *p*; but to render it stable and useful requires an arrangement of gabions and fascines, as seen in this figure, crowned with loop-holes formed by sand bags: the steps, *s*, *s*, are eighteen inches high, and eighteen inches broad, with a good tread or terre-pleine *r* in their rear of four or five feet; so that there will be no necessity to descend into the trench to reload: in the execution of this work the original sap is filled in.

287. The situation and elevation of the trench cavaliers greatly mask the fire on the howitzer batteries on the demi-parallels, as well as those for enfilade on the first parallel; and if possible their construction should be dispensed with; indeed from the increased power of the modern howitzers and the substitution of shells, spherical case, canister, and grape, for musketry, it is presumed, that the defenders and their traverses will be sufficiently swept away from the covered way by the fire of the artillery, without the necessity of resorting to the laborious and awkward construction of trench cavaliers: in place of which small mortars may be established in the same positions. At the late siege of the citadel of Antwerp, no cavaliers of trenches were constructed: but howitzer and vertical fire, especially from a great number of Coëhorn mortars, was much multiplied from the foot of the glacis. But whatever may be the arrangement, the fire of the covered-way must be quite subdued, and the defenders driven from it, ere the saps are pushed beyond the trench cavaliers.[*]

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[*] In the American campaign of 1781, General Greene attacked the fortified post of ninety-six, defended by Colonel Cruger and five hundred British soldiers. After pushing on his works with vigour, and

288. While the circular portions and the trench cavaliers have been constructing on the three capitals as specified, double and direct saps with lock traverses *k k*, fig. 124 will have been pushed from the third parallel upon the capitals of the re-entering places of arms of the front attacked; on arriving within twenty feet of the crest of the glacis, the brigades separate and become single saps, proceed to connect themselves with those on the salient places of arms, who have, in the mean time, struck out double saps *h h*, fig. 125, the direction of which fall just within the prolongations of the branches of the covered-way: meeting at *l* within twenty feet of the crest of the glacis, single saps are driven parallel to the crest, to join those coming from the re-entering places of arms; thus the whole of the crest of the glacis on the front of attack from *t* to *e*, fig. 124, is crowned, and emplacements are immediately prepared in it for the *counter and breaching batteries.*

289. The counterbatteries *b*, *c*, *f*, *d*, fig. 124, have each a space of (20 toises when the ditches are dry, that is) 120 feet; upon which six pieces of artillery can be placed, to counterbatter such of the remaining defences as may be still active upon the flanks, denoted by the accented letters *b c f d* respectively; these flanks, however, will have previously suffered greatly from the enfilade fire of the howitzer batteries on the demi-parallels and of the mortars from the third parallel, (see fig. 123 where the lines of fire from the howitzers *d d*, and the mortars *n n*, are shown), so that six pieces will rarely be required for counterbattering them: but it is absolutely necessary completely to overcome the flanking defences of the place that the ditches may be crossed in security; and should the counterbatteries have any difficulty in subduing the fire of the flanks, enfilading batteries, *t t*, fig. 124, may be added to assist, and to secure a

arriving within six yards of the ditch, he is said to have erected a cavalier of trench of the incredible height of *thirty feet*, from which his riflemen poured their shot with fatal aim upon the defenders.

preponderating fire for the assailants. These batteries, *tt*, by firing through the open space between the tenaille and the flank of the bastion may greatly alarm the defenders for the safety of their retrenchment as an assault of the breach *y* would turn the retrenchment *v*. The traverses at the re-entering places of arms must be either cut or blown away, that the guns at *t* may have a free range. A plan and section of a counterbattery is shown in figs. 125 and 126; the original sap is enlarged to give a space *m* amply sufficient for the platforms and the service of the artillery; that is, to a breadth of 20 or 24 feet: the flanks of the battery are protected by good traverses; but in those parts of the crowning of the covered-way, where it is not necessary to place batteries of artillery, the trench in rear of the parapet need not have a greater breadth than from 8 to 12 feet; and traverses must be constructed wherever it may be necessary, in order to cover its interior from flanking fire, or to afford shelter from bursting shells. At the salient place of arms before the ravelin on the front of attack, the counterbatteries *i* and *o* (fig. 124) are constructed to silence the defences *i* and *o* (accented) that flank the ditch of the ravelin: thus the besiegers obtain a full command of the ditches on the fronts attacked, and by keeping the fire of the defensive works under, the operation of crossing the ditches and taking possession of the breaches becomes a comparatively safe proceeding. The batteries *i* and *o* having obtained the superiority over the defences *i*, *o* (accented) fig. 124, the ditch of the ravelin is entirely under the command of the besiegers, who may descend into it when it is dry, and sap along its bottom as *z z* towards the breaches *i*, *o* (accented) a threatened attack at the shoulder angle as at *o* (accented) makes the defenders very jealous of their retrenchment *u* being turned.

290. Besides the counterbatteries, batteries to breach are constructed on the crowning of the glacis opposite to such portions of the faces of the works as are selected for that purpose: for example in fig. 124, the battery *s* is armed with four or five hundred 24-pounders in order to breach the revête-

ment *s* (accented) to make it fit either to assault, or to carry the sap up its slope; the battery *r*, in like manner, is to breach the revêtement *r* (accented) of the ravelin. After breaching, should the soil of the rampart stand stiffly, large shells filled with powder, having long fuzes, thrown in will act as fougasses and bring it down; the breaching batteries must be in action by night as well as day, to keep the enemy from stockading the breach, or rendering it impracticable.

291. The combined fire of these batteries on the crest of the glacis must uncover the interior of the enemy's works as much as possible, by destroying the parapets; and, assisted by riflemen from loop-holed cover of sand-bags, &c., the enemy must be quite kept down. The defenders must have no rest; the unceasing, irresistible, and concentrated fire of one hundred pieces of artillery from the first parallel, followed subsequently by the fire from the powerful howitzers on the demi-parallels, from the mortars on the third parallel, and, lastly, from the counter and breaching batteries upon the crest of the glacis, (which are still aided by batteries No. 1 and 9 on the first parallel (fig. 122) and by the fire of the howitzer and mortars on the demi-parallel and third parallel: but the fire from the batteries 2, 3, 4, 5, 6, 7, and 8, fig. 122, will be greatly, if not entirely, masked by the crowning of the covered-way).* This combined fire is of a nature so overpowering, tearing up and destroying every thing opposed to it, that the operation of seizing the other works will be far less destructive than is, at first sight, imagined.

292. It is calculated that by the fifteenth night the counter and breaching batteries can be finished and armed; and the descents into the ditches commenced opposite to the breaches.

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* "In consequence of the establishment of the breaching and counter-batteries, and the boyaus of communication crowning the two glaces, it was necessary to stop the fire of several of the besieging batteries in their rear, and to confine the discharge to that of mortars and howitzers." *Relation of the Siege of Antwerp, in* 1832, *vide United Service Journal, No.* 52

293. *Descent of the ditch*, (see figs. 127, 138, 139). This is by a subterranean gallery, whenever the counterscarp is sufficiently elevated to preserve a covering of three feet between the top of the gallery and the terre-pleine of the covered-way; miners deem this thickness necessary, in ground of ordinary tenacity, that the work may not be of too difficult, or too slow, an execution: besides which, it is necessary to protect the top of the gallery against vertical projectiles.

The height of the gallery of descent is from 6 to 6½ feet: the breadth varies according to the difficulty of working in the ground: in common soil, it is six feet in the clear: in looser soil it is prudent to limit it to four feet three inches. The gallery usually opens at three feet from the bottom of a dry ditch, and at 15 or 16 inches above the highest level of the water in a wet ditch. It ought to be driven as much as possible in a straight line, since changes of direction are of slow and difficult construction, and render the communication less commodious. Its general slope ought not to exceed a quarter, that is, the base of the whole gallery should be at least equal to four times the height; but it is not indispensable that this slope be uniform in the whole extent of the descent. The commencement of the gallery of descent is usually from some of the trenches upon the glacis: but a gallery 6½ feet high, with a thickness of three feet of soil over it, would require the trench to be deepened, at the point of commencement, to about 11 feet below the surface of the ground, in order to have the sole of the gallery at a proper depth; this mode is sometimes followed, but it is said to occupy too much time and labour, and an entrance of this kind requires great sloping sides to give it an easy access; thus forming a kind of trap for the shells of the defenders, (see figs. 138 and 139). It is therefore more generally recommended to begin the descent by a blinded gallery as *a* in fig. 127, the bottom of which would be only a few inches below the level of the trench of the regular sap whence it is struck out; and not to begin the subterranean gallery until the excavation reaches a depth of eleven feet, as in *c c*, fig. 127.

When the ditch has little depth, advantage is taken of the traverses of the covered-way, to obtain cover by running the gallery underneath the mass of one of them as in figs. 128 and 129; here the blinded part opens into the defile of the traverse at three feet below the terre-pleine, in order to enter the gallery into the profile of the traverse: the defile or crotchet of the traverse should be masked by gabions *a a*, figs. 128 and 129.

It may be remarked that this work gives the means of descending into the covered-way; as from the defile of the traverse, saps can open into the terre-pleine, to establish lodgments upon it when necessary.

A subterranean descent of 6½ feet in height and of an equal breadth advances at the rate of three feet in six hours, in fair soil. Six or eight miners are employed upon it who are relieved every four or six hours.

294. *The blinded descent* consists of a deep sap, which is covered in proportion as it advances by fascines supported by blinds; (these blinds or frames are of the size and shape shown in fig. 130); the work has a height and also a breadth of 6½ feet; which involves the necessity of carrying the depth of the sap to 7½ feet in order to give stability to the lateral blinds.

The point of the departure is usually in the crowning of the covered-way at about five feet below the surface of the glacis, a depth convenient for loading the blinds with a certain mass of fascines and of earth, without overtopping the parapets of the adjoining trenches. The point of issue being also fixed, (in a subterranean descent at three feet from the bottom of a dry ditch; or at fifteen or sixteen inches above the highest level of the water in a wet ditch). The direction of the descent between these two points should be in a straight line, its inclination not exceeding one quarter of its height. In the case where this maximum of inclination would be insufficient to bring the descent to the required point of exit, it would be necessary to sink below five feet at the point of departure.

The mode of beginning the work is seen in figs. 131 and 132; where the opening from the crowning of the covered way is represented by a double sap, pushed through the parapet of the trench, the breadth of which at bottom is seven feet; and the depth increased to five feet, (that is, two feet below the original trench); for about a space *s r o p*, fig. 131, *o p*, fig. 132: the sole of it is then sloped and deepened as *p D* fig. 132, to gain a depth of seven feet and a half: a vertical blind is then placed on each side of the sap, connected together at top by a strong piece of timber; above, is placed a horizontal blind, sustained in front by a temporary frame (as *s* fig. 135): two or three vertical blinds are thus placed on each side; the whole is covered by blind fascines (of dimensions made to suit the excavation), and, to prevent their being fired, fresh bullock hides are bound over them.

Figs 133 and 134 show a plan and section of a delicate part of the operation; that of pushing on this descent into the covered way; and fig. 134 indicates the mode in which the crest of the glacis is cut away by degrees that the sap-roller, *r r r*, may be brought gradually down to cover the head of the sap: fig. 135 shows the continuation of the blinded descent towards the counterscarp of a wet ditch, lined by fascines at the side as well as covered by them at top: fig. 136 is an elevation on *NO* of fig. 135: and fig. 137 a section on *P Q* of fig. 135: these figures are sufficiently explanatory of the process to dispense with further explanation.

295. This descent, then, into the ditch is made in two ways; either by a blinded gallery to reach the bottom of a shallow ditch, or the surface of the water of a wet ditch: or, by a descending subterranean gallery driven under the mass of the covered-way and isuing out at three feet of the bottom of a dry ditch: nevertheless when the fire of the defensive works has been fully subdued and is quite kept under, the parapets

destroyed, and the means of disturbing the descent at an end, it may be made by an open descending double sap, which, being difficult to defilade, should be made narrower and deeper than an ordinary sap; advantage being taken of a traverse to secure the sap as much as possible, as seen in fig. 125: *o p* being the sap or ramp protected by the traverse *S;* the counterscarp at *p* being blown in by a mine.

Blinded descents are very laborious in their construction, and if the soil be chalky or favourable for driving subterranean galleries, a preference would probably be given to them; and they would be constructed in the manner represented in figs. 138 and 139; by deepening the original trench on the crowning of the covered-way (as *A*) about eight or nine feet, so as to begin the gallery *B* at once: the steps leading to the entrance *A* should be formed with good planking; otherwise they would soon be worn away into a steep slippery ramp by constant use.

It is usual to make recesses (*cc*, fig 138) on each side of the extremity of the gallery behind the revêtement, in which to collect materials for crossing the ditch: these chambers are most useful for the engineers and sappers in the difficult operation of crossing a wet ditch.

In the relation of the siege of Antwerp, in 1832, in the *United Service Journal, No.* 52, are the following notices on the descents into the ditch: "The covered way of Toledo was crowned before dusk as far as the point intended for the establishment of the counterbattery, No. 15, and the descent into the ditch prepared for placing the first chassis. The shaft was about seven feet in height, by six broad: the solidity and beauty of this work was highly creditable to the French miners. A small advanced gallery was run nearly parallel to the revêtement of the counterscarp and the ground secured in case of countermining. Nothing having been discovered, the work proceeded with security. A second descent, commencing *à ciel ouvert,* was opened a little to the right of the principal shaft. It was intended to run this down to the counterscarp by a blinded covering, and connect it with the great descent by a short gallery parallel to the ditch. The grand descent was commenced at thirty-five yards from the outward revêtement of the counterscarp, and had an inclination of one-twelfth. Its breadth was six feet and its height seven. To prevent accidents the roof was double framed. The mouth of the smaller descent was pierced at twelve yards from the outward revêtement, and had about three by six feet aperture; the inclination of the latter was one-sixth. The attention of the besieging engineers was now almost entirely directed to the completion of the descents and preparations for the passage. The sections of barrels and prismatic hollow troughs, twelve of each, with the necessary tackle, weights, and tools, intended to form the arches, were brought up to the neighbourhood of the second parallel, and an abundant supply of fascines, sand-bags, saucissons, and gabions.—22d. December. The left gallery was completely framed down to the revêtement of the counterscarp, and was pierced so as to afford an arched opening of about four feet wide and three in height. The left descent was also blinded down to the revêtement, and the miners commenced opening the latter. The lateral gallery of communication was also blinded, and the whole was in a state to admit the immediate commencement of the passage, for which the materials above mentioned were in readiness to be employed on the subsequent night; when the citadel surrendered."

296. *Passage of the ditch.* When the ditch is dry this passage consists of an ordinary sap, pushed from the opening of the gallery of descent to the slope of the breach, as in figs. 138 and 139, where *s* represents the process of the sap, which is carried in the direction *r r*, to crown the summit of the breach at *P*. In crossing a ditch protected by the fire of the counter and breaching batteries, the interruption to the work from the defences cannot be very vigorous, and a single sap will suffice, having its parapet on the exposed side.

297. If the ditch be full of water, and the locality favours the draining of it, every means must be used to break the bater-

deaux to cause the water to flow away, if not altogether, at least in part; and should none of the batteries on the crowning of the glacis, or those formed in the covered-way, be able to see the baterdeaux, these sluices must be sought for and destroyed by large shells, or, if possible, galleries for mining them must be driven from the nearest part of the establishment on the covered-way.

Should the water in the ditches be subject to the ebbing and flowing of the tide, the destruction of the baterdeaux will at least secure to the assailants the advantage of having the ditches dry, or nearly so, for the periods of low tide, and thus facilitate the means of crossing it, either by permitting the storming party to assault the breach at low water; or, if the slower and surer mode of making a causeway across be followed, the foundation of it can be more securely laid.

If the assailant has not the means of arresting the current of the water, or of draining or turning it, it becomes necessary to construct either a bridge or a causeway, with a solidity amply sufficient to prevent it from being carried away. This operation is one of the most difficult in the siege: it is even impossible to execute it unless the defences of the enemy should be totally ruined by a correct and well sustained fire from all the batteries.

The dike or bridge, with its epaulement, is constructed with fascines, hurdles, joists, gabions, and sand-bags. When the water is stagnant, this work is conducted to the foot of the breach, but when it is running, or can be made so, an issue is left for it at the foot of the breach, of from eighteen to twenty-five feet, across which a float of rafts is thrown to complete the passage.

To begin this work, see figs. 140 and 141, the gallery of descent is lined with men at about two paces from each other, in order to hand along fascines and materials to the sappers at the head of the gallery: these are arranged in beds, picketted together and thrown into a ditch; first a longitudinal bed, then a transverse bed; they are arranged by the sappers by long forks from the mouth of the gallery of descent, and when sufficient to bear an epaulement on the side from which the enemy's fire comes, layers of fascines and sand bags are thrown on that side, behind which the sappers descend upon the platform in order to arrange the beds and picket them firmly together, to enlarge the surface of the bridge, and to complete the work: these beds of fascines will not sink below eighteen or twenty-four inches, and as it is necessary that they should have a certain depth and stability, they must be weighed down by hurdles and sand-bags to a depth of three or four feet: it is recommended to place strong joists or beams, from four to six inches thick, between every three or four beds of fascines, in the direction of the length of the bridge. Wooden pins, three feet long, and pointed at both ends, are fixed through these joists at every four feet, and being driven into the beds of fascines above and below the joists, bind the work well together. In proportion as the work advances towards the breach, the sappers secure it by means of anchors upon the side from which the stream flows. These anchors are attached to the upper row of joists by cables. Each cable is in two folds, as seen in fig. 141; one end fastened to the joist; and after passing through the ring of the anchor, the other end is free upon the top of the bridge, so as to veer out or contract at pleasure, as the level of the water rises or falls; as the bridge advances, a good epaulement of gabions filled with sand bags, fascines, &c., is formed: the bridge should be from thirty or thirty-six feet broad at top, as the epaulement will occupy fifteen or eighteen feet. Fig. 140 shows a longitudinal section and fig. 141 a transverse section of this work: and as the defenders will doubtless endeavour to burn this bridge, every precaution is taken to prevent it by covering the epaulement with horse dung and fresh killed bullock hides.

In Vauban's *Traité de l'Attaque des Places*" there are the following remarks on this subject. "Let us suppose the ditch of a place, through which passes a considerable current, supplied by a river, or by a reservoir, that furnishes the water by means of sluices giving currents at will; it is certain that the current will continue, strong or weak, and be repeated from time to time by means of the sluices; here the assailant has no other means than that of making a large dike or causeway across the ditch, of a size sufficient to arrest the waters at the same height that the sluices can retain them; so that the highest level of the water cannot come within two feet of the top of the causeway. To this end, it becomes necessary to collect a great mass of fascines with stones, rubbish, and earth, in order to sink them fully to the bottom; to make the causeway broad and very strong by beating down the earth, and piling the work to the bottom of the ditch; this causeway is pushed to within eighteen or twenty-four feet of the foot of the scarp revêtement, and a lighter floating bridge made to complete the passage: or when assured that the head of the dike is so high that the swelling of the water cannot surmount it, a lively fire from the breaching batteries upon the revêtement opposite, will beat it down into the ditch and complete the passage.

"When a ditch is deep and narrow, an excellent means of forming a passage is to attach two miners, one to the scarp and the other to the counterscarp opposite to each other; if the mines be large and well charged, it is probable that their effect will fill the ditch at once, especially if the arrested water cannot rise more than five or six feet above the current; it was thus that we proposed passing the ditch of the gate of Anzin at Valenciennes, if the resistance of the place had obliged us to go so far."

298. Should the attacked work be without retrenchments and have unflanked ditches, the bridge need only be slight, as it will merely have to bear the assaulting party: but if any flanking fire can be brought upon the ditches, and if there should be a retrenchment that demands an establishment for batteries to be formed on the summit of the breach, in order to reduce it, the bridge must be solidly formed to bear the transport of artillery, and the construction of a good epaulement.

One mode of passing a wet ditch, is to construct a raft with an epaulement upon it, along the counterscarp; and when complete, to fix one end at the bottom of the descent and to allow it to swing round with the current, or in stagnant water, by means of poles or oars, so that the other extremity may reach the rubbish of the breach.

On the completion of the passage of the ditch, the breaching batteries render the breach as gentle and practicable as possible either by round shot or shells, as required ; a few brave and intelligent sappers glide up the breach and reconnoitre the interior of the work, under vollies of uncharged shells and blank cartridge.

If there should not be any retrenchments behind the breaches, or, if they should appear weak and imperfect, every necessary disposition is made for the assault of all works at the same time, that is, of the two half bastions on the front attacked, and of the ravelin between them ; the latter being assaulted by the breach, and, if the ditch be dry, by the gorge also : and if an enemy has no other resource than that of standing the assault, he should beat the *chamade*. This will be from the twentieth or twenty-fourth day from the opening of the trenches.

But if the ravelin has a redoubt, and if the bastion be retrenched, it is necessary to carry on the attack by pushing a regular sap up the breach, and forming a lodgment within the work for the attack of the remaining defences in form.*

299. Speaking of the breach in the ravelin, Marshal Vauban thus expresses himself: (see Jones's Sieges, vol. 2, page 272.)

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* At the siege of Cambray, Dumetz stormed a ravelin contrary to the advice of Vauban, and sustained a loss of forty officers and four hundred men ; two days afterwards, Vauban retook it by sap, and lost three men.

"Preparatory to making the lodgment a great quantity of materials must be provided, such as gabions, fascines, and sand-bags, and also a number of entrenching tools; which should be carried as far forward as possible, without encumbering the trenches, and piled on the reverse of them. Care must be taken that all the lodgments from which it is possible to fire on the part to be attacked, are in a perfect state, and that the batteries of cannon, mortars, and pierriers, are in readiness to open; and the officers commanding in the batteries and lodgments, should have it fully explained to them on the spot, how they are to act according to the signals made.

"The signal may be from a flag elevated on the lodgment of the covered-way, at such spot as shall be seen from all the batteries and lodgments. Every thing being ready, the infantry will place their muskets through the sand-bags laid for their protection on the top of the parapets, and every one will await in silence the signal to open his fire by the flag being hoisted, and to cease firing on its being lowered.

"Thus prepared, two or three sappers will ascend the breach —not up the centre, but on its right and left, next the end of the broken wall, where cover is usually found between the part of the revêtement which remains standing, and that which has been beaten down. The two or three sappers will lodge themselves in these hollows, throwing the rubbish down, but working upwards, and will procure cover for two or three other sappers, who will be sent to their assistance, the whole being prepared to leave their work on any advance of the enemy. Should that occur, as soon as the sappers are off the breach the signal is made, and all the batteries and lodgments instantly open a heavy fire on the enemy, who cannot remain under it, but will quickly disperse. As soon as that is perceived the flag must be lowered, and the sappers again sent forward, who, resuming their work, will push it forward as much as possible; again abandoning it, however, whenever the enemy make their appearance, which may occur a second, and even a third time.

Each time, however, that they do come forward, all the lodgments and batteries, even those of the covered-way, must resume their fire, which cannot fail to drive back the enemy, and give opportunity to establish the lodgment. It will not probably be till the first or second time of returning that the garrison will spring their mines, (if there be any), and which may be considered an infallible sign that they give up the work. These mines are unlikely to be attended with any great effect, for they may be sprung at a moment when the workmen are not on the breach; or they may have been formed under the ridge, where the sappers do not work, or at worst can only destroy three or four men. In the mean time the sappers will have prepared some cover in the excavation, which when completely ready, and not till then, must be occupied by small detachments; but as soon as the garrison abandon the work, the lodgment must be made openly in the breach, and be well secured along the whole excavation, but not beyond it. Afterwards the work will be extended to the right and left along the rampart by saps, forming a portion of a circle which will occupy all the terre-plein of its flanked angle: from thence it will be carried along the two faces of the work till every thing is duly prepared to force the retrenchment at the gorge."

300. The summit of the breach being gained, and a lodgment made upon it by the sap, the ulterior operations depend on the nature of the retrenchments. Should the ravelin on the front of attack be provided with a redoubt, the breaches in the adjoining bastions cannot be seized till the flanks of this redoubt that bear upon them are silenced: thus, in fig. 124, if the ravelin be furnished by a redoubt, (1), the flanks of which carry guns bearing upon the faces of the collateral bastions, the sap *r* (accented) is carried up to form the lodgment 2, 2, within the flanked angle of the ravelin, as *r r P*, fig. 138 and 139, in order to silence the flanking defences of the ditch of the redoubt, and to breach its scarp. Its ditch is passed in the manner hitherto described;

and, when captured, a battery is formed in its gorge, to aid the further operations against the enceinte.

In like manner, if the bastion be retrenched, the sap *a*, (accented) fig. 124, is carried up the breach, and a lodgment, 3, formed within the flanked angle, the fire of which, supported by that of the batteries of guns, howitzers, and mortars in its rear, will surely overpower the remaining feeble defences, and enable the assailants to proceed to the assault, should the besieged risk this fatal proceeding.

"A fortified place can only protect the garrison and arrest the enemy for a certain time. When this time is elapsed, and the defences are destroyed, the garrison should lay down its arms. All civilized nations are agreed on this point, and there never has been an argument, except with reference to the greater or less degree of defence, which a governor is bound to make before he capitulates. At the same time there are generals, Villars among the number, who are of opinion that a governor should never surrender, but that in the last extremity he should blow up the fortifications, and take advantage of the night, to cut his way through the besieging army. Where he is unable to blow up the fortification, he may always retire, say they, with his garrison, and save the men.

"Officers who have adopted this line of conduct have brought off three-fourths of their garrison.

"The keys of a fortress are well worth the retirement of the garrison, when it is resolved to yield only on those conditions. On this principle it is always wiser to grant an honourable capitulation to a garrison, which has made a vigorous resistance, than to risk an assault."—*Military Maxims of Napoleon.*

Marshal Villars has justly observed, "that no governor of a place should be permitted to excuse himself for surrendering, on the ground of wishing to preserve the king's troops. Every garrison that displays courage will escape being prisoners of war. For there is no general, who, however well assured of carrying a place by assault, will not prefer granting terms of capitulation rather than risk the loss of a thousand men in forcing determined troops to surrender."

Vauban is reported to have said, that amongst the multitude of the gallant and devoted officers of his day, he knew but few fitted to be governors of a besieged place: and in the note to Napoleon's Maxims there is the following sentence: " All real strength is founded in the mind: and on this account I am of opinion that we should be directed in the choice of a governor, less by his genius than his personal character. His most essential qualities should be courage, perseverance, and soldier-like devotedness. Above all, he should possess the talent, not only of infusing courage into the garrison, but of kindling a spirit of resistance in the whole population. Where this last is wanting, however art may multiply the defences of a place, the garrison will be compelled to capitulate, after having sustained the first, or at most, the second assault."

301. *Number of men required to carry on a siege with vigour.*—From Sir John Jones's Sieges, vol. 2, note 28.

"The number of men necessary to carry on a siege with vigour, is founded on principles, always remaining the same; but varying in certain contingencies of which the commander of the army is alone capable of judging. He has first to decide how many reliefs the troops shall have, that is the proportion of rest to duty, and also the number of his troops which he deems equal to cope with the garrison; and then the detail follows as matter of course. The following seems the minimum of the calculation.

" Guard of the trenches, three-fourths of the strength of the garrison. This duty may be taken for a short service with three reliefs. The workmen, however, cannot do with less than four reliefs. Their numbers depend upon the trace of the work to be attacked; but, for the sake of calculation, let the operation against a common front of 180 toises with a ravelin be assumed. Then the length of the first parallel, and one line of approach to it, which should always be opened on the night of breaking ground, measures 3,800 yards; which, at four feet apart, require 2,850 men to line them, and that number will, consequently, be the strength of the first night's working-party. The second night the same number of workmen will be required; and what with the service of the artillery and the transport of materials, but small deduction can be made from their strength till the completion of the second parallel. For the remainder of the siege much fewer will suffice; therefore, by arrangement and a little extra fatigue on the first days of the attack, the working parties may be averaged at one-third less than the party of the first night, or, in round numbers, 2,000 men.

"For regimental and camp duties, pickets, escorts, with stores and provisions, &c., the proportion of the army required will vary according to the hostility of the people in whose country the siege is carried on, and it is one of the contingencies to be regulated by the general commanding; but being fixed, their reliefs must be equally regular with the others. For the sake of calculation, it shall here be stated at one-tenth of the whole army.

"On these data, the amount of an army required for the vigorous siege of a place with a garrison of 5,000 men would be,

Guard of the trenches 3,750, at three reliefs,	11,250
Working-parties 2,000, at four reliefs, ...	8,000
	19,250
Duties of the army one-tenth, at four reliefs,	7,700
Total, independent of sick and casualties,	26,950

"From this calculation, it is evident, cæteris paribus, that the more numerous the garrison, the smaller the besieging army need be in proportion to it; for the attack of a similar front or fronts of fortification is little different, if the place contain a garrison of 5 or a garrison of 10,000 men; the guards of the trenches and the other duties increase proportionately, but the work does not.

"The calculation for the attack of a garrison of 10,000 men would be,

Guard of the trenches 7,500, at three reliefs . .	22,500
Working parties 2,000 men, at four reliefs . . .	8,000
	30,500
Duties of the army one tenth, at four reliefs. . .	12,200
Total, independent of sick and casualties . .	42,700

"The former being nearly in the proportion of 5 to 1, and the latter of 4 to 1. Hence it is that the most celebrated commanders and best engineers are agreed as a general principle, that the besieging army should vary in its proportion to the strength of the garrison according to the numbers of the garrison; and as an approximation have fixed that proportion at 5 to 1 when the garrison consists of 15,000 men, 6 to 1 when of 10,000 men, 7 to 1 when of 5,000, 8 to 1 when of 3,000, and in still greater proportion when it consists of a less number.

"If there be any cavalry in the place, the guard of the trenches requires to be supported by a number of cavalry equal to the total of that arm in the garrison, with a reserve of one-half more posted at the mouth of the trenches; for as cavalry act invariably on the flanks of the trenches, the cavalry guard on each flank ought to be prepared to oppose all the cavalry in the garrison; and, by such an arrangement, this will be the case, the body of one-half held in reserve being in a situation to support either flank, and make it of equal strength with the whole number in the garrison. The sortie of the 19th March, 1812, from Badajos, is a remarkable instance of how much a few cavalry may effect if not opposed by cavalry; forty or fifty men, on that day, having carried confusion into the very depôts of the artillery and engineers, and made officers prisoners at nearly 2,000 yards from the place.

"These calculations do not apply to peninsula-fortresses on a restricted front; but in all open situations, an army formed on the above calculation would, at the end of a siege of a month's duration, be greatly fatigued.

"It is not, however, intended to convey the impression that a siege should never be undertaken unless with a force thus proportionably greater than the garrison; but merely to point out where choice exists the best rule of proceeding. All general rules must occasionally be deviated from; genius will sometimes supply the place of numbers, and necessity oblige where calculation condemns.

"Thus, in consequence of the superior strength of the French in the field, and the immediate vicinity of their principal armies, which required strong detachments to watch, and an efficient corps to parry their hostile movements, the Duke of Wellington, in 1812, could only allot 12,000 men (increased to 16,000 on the day of the assault) for the siege of Badajos, garrisoned by 5,000 men, and, nevertheless, breached and carried the place by assault in an unusually short period; and again, at the siege of St. Sebastian, in the following year, (a peninsula-fortress,) 11,000 men triumphed over 3,400."

302. *On the quantity of ordnance required to carry on a siege with vigour.*---From Sir John Jones's Sieges, note 29.

"The number of pieces of ordnance required for the attack of a fortress has not so much reference to the number of pieces mounted on its ramparts, as to the construction of the works themselves which they are intended to defend; for the besiegers never willingly oppose artillery by a direct fire, but generally contrive, by a skilful disposition of their trenches and batteries, to render one piece of ordnance in the attack superior to several in the place.

"Thus, for instance, three guns firing à ricochet from any convenient point (not being a greater range than 600 yards) on the prolongation of a face or other line without traverses, will dismount any number of guns, say ten or twelve, which may be mounted upon it; or if the line be traversed, they only require the aid of shells from two or three mortars to ensure the same effect, and such a position for the besiegers' batteries may be found on the prolongation of most of the lines of ordinary works.

"There will, however, be in all irregular, mountain, and maritime fortresses, many faces against which an enfilade fire cannot be made available, such as portion of works formed with a considerable curve, or where, by a skilful disposition of the defensive lines, their prolongations are made to fall on situations where batteries cannot be erected, as a hollow, an inundation, a river, the sea, or that they are made to intersect other portions of the work which cover and conceal their ramparts; or where the works stand on very great elevations, or are naturally shouldered in by higher ground on their immediate flanks. In these cases the ordnance of the place must be silenced by direct fire from the besiegers' trenches, and such fire, to be effectual, ought at least to be equal in weight and quantity to that it is intended to silence.

"A battery, thus firing from the trenches, has this advantage over the batteries of the place, that its undivided attention can be given to one object; whereas, the defensive ordnance must occasionally be diverted to efforts to arrest the progress of the works of the attack. Therefore, gun for gun, and mortar for mortar, the besiegers would generally succeed in overpowering the fire of a place; but where ordnance can be procured, double the amount of that to be silenced by direct fire should be brought into the trenches, which would effect the object in far less than half the time.

"In future sieges, the recently invented 10 and 8-inch howitzers of Monsieur Paixham and General Millar will, without doubt, be the principal weapons for enfilade fire, and will tear up every thing opposed to them; but where guns continue to be used, the 18-pounders will be found handy and efficient.

"For direct fire or breaching, no gun of less calibre than a 24-pounder should be used.

"Therefore, to carry on the attack of any place, however fortified, with speed and little loss, there should be provided to be put in battery, immediately after breaking ground, an equal, or if possible, double the number of guns to those in the place which it may be found necessary to oppose by direct fire; and from three to five 18-pounders or heavy howitzers for every line bearing on the attack subject to be enfiladed. Five pieces to be used against the principal faces and longest lines, and three against the shorter lines. To render their fire effectual, however, it is *absolutely necessary*, that two or three 8 or 10-inch mortars should be planted in each of the principal batteries to destroy the defensive traverses, and search into such parts of the enfiladed line as may be sheltered from the ricochet of guns.

"If there be a covered-way, two or three of the heaviest nature of howitzers in addition to the above will be required to sweep each of its faces, when the approaches arrive at 150 or 160 yards from their salients; and three or four pierriers or mortars, charged with small balls, to overwhelm the defenders of each of the re-entering places of arms, when the approaches arrive at 60 or 70 yards from the covered-way.

"Such a provision of ordnance will serve to gain possession of the covered-way of any ordinary fortress; but, for the further prosecution of the attack from that point, other fifty pieces of ordnance, firing with the full charge, should be provided.

"The detail of the natures of ordnance at future sieges will differ greatly from that laid down by theoretical writers on the attack and defence of places, who invariably calculate and reason on the effect of ordnance as being the same as in the time of Vauban; whereas, the powers of each calibre of gun and howitzer has doubled in force since that period, and such is now the accuracy of their shooting, that the fire of the first batteries might be rendered serviceable (if required) till the passage of the ditch.

"Again, the recent improvement in the 8 and 10-inch howitzers, having increased their range and rendered their shooting accurate, they will naturally in future sieges be made to supplant most of the guns hitherto used for enfilading, and will be the means of clearing the covered-way and re-entering places of arms, with far less aid from advanced batteries than hitherto effected.

"The practice with small mortars has also become so correct, that they might be used with the greatest effect as temporary expedients, and would in many cases obviate the necessity for bringing up more unwieldy machines.*

"Spherical case will also naturally be substituted for musketry in many situations, and will prove of essential service.

"The exact number of pieces of ordnance required for the reduction of a fortress can only be distinctly ascertained by the joint labours of the heads of the artillery and engineers' service, after the plan of the attack shall have been decided; but, as some approximation is necessary for the previous outfit, it may be stated, that the smallest number of pieces, which any calculation will admit for the reduction of a front with a ravelin, is 60 guns, 20 howitzers, 22 mortars, and 16 pierriers; and that to carry on the attack with due convenience and vigour, there should be a battering train composed as follows:—

24-pounders	40
18-pounders or heavy howitzers	80
Mortars of 8-inch and upwards *with shells*	30
Do. do. used as pierriers	16."

In fig, 122, there are nine ricochet batteries on the first parallel; let No. 2, 5, and 8 have six guns each (No. 5 being a double battery) against the faces of the bastions and their covered-way; let No. 1, 3, 4, 6, 7, and 9 have five guns each to enfilade the faces of the ravelins and their covered-way: and let batteries *a* and *b* be armed with six pieces, each for direct fire against the faces *d* and c of the extreme bastions; *a* and *b* being armed with 24-pounders, and all the other batteries with long (8 or 10 inch) howitzers or 18-pounders; this gives 66 guns and howitzers; add three mortars for each of the eleven batteries; and the total will be sixty-six guns and howitzers, and thirty-three mortars, for the attack of one front on a hexagon. Here, then, by fig. 122, there is a fire from one hundred pieces of artillery, that have their choice of position, concentrated on the fronts attacked; each battery has a specific object; and even such shot as do not exactly answer their intended purposes are still injurious to the defences; for example, batteries No. 1 and 9 are to enfilade the right and left faces of the extreme ravelins; but missing that, the curtain *e* is exposed to their effect."

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* The author saw the Prussians firing from their trenches before Maubeuge from mortars of four inches and two-fifths, on the morning after breaking ground. The mortars were placed on the bottom of the trench (a firm gravel) without platforms, and were throwing a succession of shells with apparent good effect into an advanced lunette, from which a musket shot only was occasionally returned. There can be no doubt that portable mortars used in such manner would prove highly serviceable at various points of an attack, and it is strongly recommended that they should form part of every battering train.

302 "*Considerations on the Quantity of Ammunition required for a Siege.*—From Sir John Jones's Sieges, note 29, (second part).

"As the enfilading batteries must continue open till the approaches arrive at the crest of the glacis, and the mortar batteries during the whole period of the attack; the ammunition of those natures, necessary for a siege of a given duration, depends in great measure on the number of rounds fired from each piece in a given time.

"At the commencement of a siege, the enfilading and mortar batteries should fire to produce their utmost effect; but after twenty-four or thirty-six hours severe firing, the traverses will be demolished, the platforms broken, and the artillery on the ramparts disabled; after which, only such fire need be maintained as will prevent working parties of the garrison repairing the injuries sustained, or bringing up fresh ordnance. For this purpose, great precision, and an equal fire day and night, will be required, and each piece should fire a regulated number of rounds per hour. As the effect of each shot must be watched, the charge accurately apportioned, and the utmost attention paid that the piece be duly regulated each time; and further, as there is much merit and real utility in expending no more ammunition than is absolutely necessary to effect an object, it would, perhaps, be better that the fire à ricochet were limited to 100 rounds in the twenty-four hours.

"The mortars in battery might probably be used to advantage to the extent of 120 rounds per day throughout the siege.

"Batteries to breach, fire as quickly as they can with precision, which may now be estimated at 25 or 30 rounds per hour; but as such rate of firing injures the guns, and further, is little likely to be maintained where opposed by musketry, the average proportion for breaching may be stated at 20 rounds per hour, for the period of day-light.

"On these data, the precise quantity of ammunition of every nature required for the reduction of any place may be calculated as soon as the plan of the attack has been laid down; but as that cannot be fully decided till after the investment, some approximation to the calculation is required for the previous outfit.

"For the attack of an ordinary front, it will be found sufficiently accurate to provide 60 rounds of shot per gun, and 60 shells per mortar, on the full proportion of ordnance, stated in the former part of this note, for each day the attack is calculated to last, or 1,200 rounds per gun and mortar, independent of shells for the howitzers, for a siege of twenty days.

"Assuming the foregoing battering train as the standard of calculation, it will naturally be understood that as a train composed of fewer pieces of ordnance will have each piece, on the aggregate, a longer time in battery, the supply of ammunition for such inferior numbers must be proportionally greater than 60 rounds per gun and mortar.

"For each pierrier there should be provided 400 rounds of half-pound and one-pound balls; and also a considerable proportion of case and grape shot for all the natures of ordnance, and at least 15,000 hand grenades. Nor should carcasses, light-balls, and rockets be spared—each will under certain circumstances prove highly serviceable. The large rockets would form batteries for many purposes, which would not wait the delay of getting up ordnance, and on points where space could not be obtained for the working of guns; and would further be tremendous weapons to sweep along a ditch, or amongst bodies of men in confined situations.

"The number and proportions of the shot being fixed, a few barrels of powder extra, will ensure a provision for firing with the full charge or à ricochet, as they may happen to vary.

"One thousand barrels of powder above the artillery demand should always be provided for engineers' services, with a quantity of slow match, portfires, &c.

"The proportions above given may appear somewhat large to an English officer accustomed to the very scanty supplies furnished for the siege equipments during the late wars, but no commander, about to undertake a siege, should be satisfied with less, for it is a fact which cannot be too much considered, that the more ample the provision of ordnance, ammunition, and materials, so much sooner will a place fall, and so much less will be the loss of the besieger.

304. *Considerations on the engineers' means, necessary to carry on a siege with vigour;* from Sir John Jones's Siege. 2d vol. Note 30.

"Next to a sufficiency of artillery and ammunition, an abundant supply of materials and stores will be found the most important aid, in reducing a place with certainty and little loss. Such abundance will facilitate the advance of the approaches, and save the lives of the troops at every step.

"Indeed, there is nothing more certain than that the reduction of a fortress must be paid for in materials or men, and that to save the one the other must be freely sacrificed.

"The cause of fortified places invariably falling under the attack of an enemy, arises conjointly from the superior fire the besiegers are able to bring against it, the unlimited quantity of materials they can expend, and the power they have of opposing on every point, a superior force to that of the garrison.

"In a town of the utmost magnitude every supply is limited; gun after gun, and platform after platform may be replaced, fresh materials may long be found to repair every casualty, and even fresh men may for some time be forthcoming to relieve those disabled; but finite means must diminish by use—the largest magazines will be ultimately expended, each succeeding day of a siege empties them in a twofold proportion, and nothing can be procured from without to replenish them; till at length, after a certain period of resistance, the garrison find all their resources exhausted, whilst the power of the attack is hourly augmenting, and only save their lives by means of a capitulation.

"In the two preceding notes, the quantity of artillery, and the number of men necessary to this due superiority of force, has been discussed.

"The quantity of materials required for any given nature of operation may, in like manner, be calculated with the utmost exactness, as soon as the plan of the attack has been laid down. The mass of gabions and fascines, by a measurement of all the lines of the trenches from the second parallel inclusive; the breadth of the ditch, the front and height of the cavaliers of the trenches, the numbers and extent of the several lodgments, &c. &c. &c.

"After making the calculation with accuracy, it will be necessary to add one half to the amount, as very considerable numbers of both fascines and gabions will be destroyed in the carriage, whole rows must occasionally be replaced, and many uses will be found for them in the progress of the work, which cannot be anticipated.

"Next come the materials for the batteries, the gabions and fascines for the cheeks of the embrazures, the sand-bags for their interior revêtements and traverses. Then sand-bags to cover the riflemen, &c. &c.; and to these quantities a very large addition must be made, as sand-bags are a reserve store of incalculable value, and the main stay of most English operations.

"In a similar manner the quantity of scantling and plank required for the galleries of mines, platforms, splinter-proofs, &c. should be calculated, and a very large addition made to the amount for unavoidable accidents and unforeseen labours.

"The entrenching tools should be, at least, in the proportion of three to one of the strength of the most numerous working party likely to be employed.

"Pick-axes and shovels cost little originally, and are not necessarily expended by use like shot or shells: one hour's firing from the batteries at a siege costs more to a state than the value of all the entrenching tools with an army.

"It will be seen by the Journals,* that owing to a deficiency of means of transport and other irremediable obstacles, the supplies of tools and stores in Spain were altogether too small, and prevented many operations being carried on which were considered desirable; and further, created innumerable difficulties and delays in performing the work which was completed. Those supplies must not, therefore, be considered any criterion of the quantities which ought to be brought up. Indeed, recent experience furnishes no data on which to form a correct idea of the quantity of materials and stores likely to be expended during a siege: but the reader is referred to the excellent memoranda published by Cormontaigne, and other practical writers, of the expenditure during the olden times of sieges; and he will there see, instead of the miserable quantities detailed in these pages, 30,000 entrenching tools, 200,000 sand-bags, 278,000 sacks of wool, 50,000 hand-grenades, 300,000 fascines, 80,000 gabions, and other similar quantities of stores and materials, brought up and expended at most of the attacks.

"Whatever be the quantity of stores, or however great the mass of materials found to be required on a calculation of the details of the several works of a siege, they should all be on the spot previously to breaking ground, or their arrival be assured at given periods of the attack. Delay, loss of life, and disaster, are the infallible consequences of any irregularity in the receipt of materials during a siege.

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* Journals of Sieges by Sir John Jones, Bart. C.B.

"With respect to the officers and men required for the engineer's service at a siege, the following is submitted as a fair proportion for carrying on the duties with vigour.

"*Officers for the General Duties of the Siege.*

"Commanding engineer, three staff, two directors, ten brigades of one captain and two subalterns each.

"The directors to be field officers; and as the senior staff officer generally acts as major des tranchées, that is, all arrangements of detail are made through him, it is desirable he should also be of field rank.

"The other officers to be either first or second captains, or first or second lieutenants, as may be convenient.

"*Men for the General Duties.*

"One company of sappers on the war establishment distributed in the proportion of ten to each brigade of officers. The officers of this company to take the general duties of the trenches as one of the ten brigades.

"The above numbers will admit of three brigades of officers and men being constantly on duty in the trenches, with one brigade spare for extra or distant services, and to replace casualties.

"*Sappers working as such.*

"Four companies on the war establishment, so as to furnish twelve brigades of eight men each company, making forty-eight brigades altogether; which, at four reliefs, would give twelve brigades, or one company, (being in round numbers 100 sappers) constantly working in the trenches. The officers of these companies to go on duty and come off duty in the trenches with the men so as also to have four reliefs.

" *Miners.*

" One company of seventy or eighty men, or a detachment of a similar number, but more strongly officered in proportion, would generally be sufficient; but should the place about to be attacked be countermined, two companies of miners must be formed. The officers of these companies or detachments to be employed on the same duties with the men.

" *Artificers.*

" One company of artificers, or a detachment of the strength of 100 carpenters, sawyers, and smiths, embodied from the sappers for the period of the siege, or obtained from the troops. These men to prepare and lay the platforms, frame the supports for the mines, repair tools, and superintend the making of fascines and gabions, mantlets, &c. &c. by a separate roster.

" The officers of this body of artificers, when composed of detachments from the troops, to take the general duties of the trenches as assistant engineers.

" *Commissaries of stores.*

" Two of senior rank, six of junior rank. The former to have charge of the park by alternate reliefs; the latter to go on duty at three reliefs; and have charge of the stores, tools, and materials, going from the park to the entrepôt or trenches, and returning from thence to the park.

"The commissariat will require three reliefs of four men each to be permanently attached to them for the whole period of the siege.

"These men might be selected from the non-commissioned officers and spare men of the companies of sappers or the artificers, and be aided in their duties as the service required it by soldiers of the line from each relief of the working party.

The sappers, miners, and artificers, when not required to work at their respective trades or occupations, to be employed by regular reliefs on the general labours of the trenches, which would be found to facilitate the construction of the batteries, magazines, &c. &c., and much diminish the number of the troops necessary to form the working parties.

"*Summary of the Engineer's Establishment for a moderate Siege.*

	Commanding Engineer.	Staff.	Directors.	Captains.	Subalterns.	Commissaries.		Companies of Men.	Companies of Artificers.
						Senior.	Junior.		
General duties	1	3	2	10	20	..	..	1	..
Sappers.......	..	..	..	4	8	..	..	4	..
Miners.........	..	..	..	2	6	..	..	2	..
Park..........	..	..	:	1	..	2	6	..	..
Artificers......	..	..	..	..	2	..	..	..	1
Total....	1	3	2	17	36	2	6	7	1

"If the attack of a fortress be attended with local difficulties, or divided into distinct operations, the above numbers of both officers and men must be very considerably augmented to ensure due efficiency."

With reference to these paragraphs (301, 302, 303 and 304) the following information is annexed on the late siege of Antwerp, extracted from the history of the operations, published in *the United Service Journal, No.* 52.

In the attack of the citadel of Antwerp in November and December, 1832, the French army under Marshal Gerard, employed in the siege, and covering the operations, amounted to 54,000 infantry, 6,000 cavalry, 6,450 engineers, artillery, pontoon train, &c.; in all 66,450 men; 14,300 horses; 144 pieces of siege, and 78 pieces of field, artillery.

The strength of the garrison of the citadel under the orders of General Chassé, amounted to 4,470 men, with 145 pieces of artillery of all calibres, and an abundant supply of ammunition and material.

All previous preparations on the part of the besiegers being completed, Marshal Gerard moved his head quarters to the village of Berchem, about 2,500 yards from the ramparts of the citadel on the 29th of November, and issued orders for commencing operations at night-fall.

At 8, p. m., the troops destined for this service consisting of 18 battillons; 900 artillery, and 400 sappers, in all about 17,140 men, assembled by detachments at the three depôts of entrenching tools. The covering parties composed of the flank companies of these brigades, supported by twelve 8-pounders and a strong picquet of cavalry debouched under cover of the walls and hedges, and were thrown out under the direction of General Haxo, by whom, and the officers of his department, (the engineers) the first parallel and its approaches were traced out; while General Neigre, and the officers of the artillery, simultaneously occupied themselves in marking the projected batteries.

15th December. The besieging army exclusively before the citadel, was augmented to upwards of 30,000 infantry; therefore including the sappers and artillery, the number of the investing and besieging corps was about 7 to 1 of the defenders.

5th December. The number of pieces of artillery in the batteries of attack, that opened on the citadel, was 105: viz. twenty-six 24-pounders; eighteen 16-pounders; forty 10-inch and 8-inch mortars; and twenty-one 8-inch howitzers.

21st December. On the breaching and counterbatteries being completed, the whole re-opened with increased vigour, and from this period to the last hour of the siege, 40 mortars, 20 howitzers, 6 pierriers, 19 Coëhorns (3½ inch bore), thirty 24-pounders, and fifteen 16-pounders, in all 130 pieces, maintained an almost incessant discharge; and yet not a single casemate in masonry had hitherto received any serious damage.

The citadel, on which this fire was concentrated, is a regular pentagon of 188 toises exterior side: want of accurate practice was inexcusable, as the maximum

Gun range was	680 yards
Howitzer ditto	850 ditto
Mortar ditto	1000 ditto

The new features in this siege in the artillery department were: 1st. the tremendous effects of the new, long howitzers (introduced into the French service by General Paixhans and into the English service by General Miller); the practice of which is well known and highly appreciated by the British and French artillerists. 2d. The increased employment of Coëhorn mortars on both sides, as the attack approached the foot of the glacis; which searched into the saps, and behind traverses; superseding, (together with howitzer shells), the necessity of cavaliers of trenches. 3d. Bringing into use an immense mortar having a calibre of twenty-four inches; the shell of which holds ninety-nine pounds of powder, and when charged, weighs one thousand and fifteen pounds; the chamber of the mortar contains thirty pounds: weight of the mortar fourteen thousand seven hundred pounds; and of the bed, sixteen thousand pounds. The utter impossibility of using such a machine, requiring transport for the enormous dead weight of about eighty tons, (except in peculiar cases, such as at the siege of Antwerp), renders it unnecessary to dwell upon the merits or demerits of this subject. 4th. The adherence of the French artillery to the use of brass battering ordnance, which is well known to possess properties very far inferior to iron guns; as indeed was shown by the disposition of the brass guns in the breaching battery, and elsewhere, to run at the vent and droop at the muzzle, although they did not exceed six or seven rounds in an hour.

Expenditure of ammunition. 23rd. December, at 10 a. m. the fire ceased entirely on both sides, having been maintained by the Dutch from mid-day on the 30th November; altogether twenty-two days and twenty-two hours: and, by the French, from 11 a. m. on 4th December, making eighteen days and twenty-three hours: the former having expended forty-two thousand rounds; and the latter upwards of sixty-three thousand; the half of which were hollow projectiles.

Taking the number of pieces in battery to have been one hundred and five, and the number of days nineteen, this will give about three thousand three hundred for the whole, per day; six hundred rounds for each piece for nineteen days, and thirty-one rounds for twenty-four hours; or, not one shot in forty minutes for each gun.

Marshal Gerard, in his report of the 13th December, says "I have given orders that our fire shall be arranged, so that there shall be continually a shot or shell in the air; the execution of this measure allows no respite to the enemy, and prevents his quitting his casemates where he has taken refuge."

Engineers' means. The supply of fascines, gabions, sand bags, platforms, entrenching tools, &c. at this siege, were most abundant.

SUPPLEMENT TO THE ATTACK.

In the Military Maxims of Napoleon,* at page 178, the following principle is laid down.

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* "The Officers' Manual.—Military Maxims of Napoleon; translated from the French by Colonel D'Aguilar, Deputy Adjutant General to the Troops serving in Ireland, 1831."—An instructive and animated little

"Fortresses are equally useful in offensive and defensive warfare. It is true, they will not in themselves arrest an army, but they are an excellent means of retarding, embarrassing, weakening, and annoying a victorious enemy."

On which the following remark is made:

"The brilliant success of the allied armies in the campaign of 1814 has given to many military men a false idea of the real value of fortresses.

"The formidable bodies that crossed the Rhine and the Alps at this period, were enabled to spare large detachments to blockade the strong places that covered the frontiers of France, without materially affecting the numerical superiority of the army which marched upon the capital. This army, therefore, was in a condition to act, without the fear of being menaced by its line of retreat.

"But at no period of military history were the armies of Europe so combined before, or governed so entirely by one common mind in the attainment of a single object. Under these circumstances, the line of fortresses which surround France was rendered unavailable during the campaign; but it would be very imprudent, therefore, to conclude, that a frontier, guarded by numerous fortreses, may be passed with impunity; or, that battles may be fought with these places in your rear, without previously besieging, or at least investing them, with sufficient forces."

When Napoleon's sun was setting he found himself in possession of many strong holds, besides the line of fortresses surrounding France, the inefficient garrisons of which he endeavoured to stimulate to the utmost defensive exertions by edicts, instructions, &c.; one of which contains so much useful matter, that the compiler has annexed nearly the whole of it; not being able to obtain the original in Paris, he has availed

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work, for which the officers of the British army are much indebted to Colonel D'Aigular, and a copy of which ought to be in the hands of every officer.

himself of the translation of Major Reid of the Royal Engineers.

"*Extracts from Instructions for the defence of fortresses, issued by the French Imperial Minister at War, in* 1813.

"1. These instructions are more particularly drawn up for governors of *great fortresses:* it is in such that the defence is most complicated: but at the same time every officer commanding in a fortress, or even in a fort that is capable of resisting a coup-de-main, will here find his duties detailed, excepting such difference as arises from the size and population.

"2. His majesty has sanctioned the distinctions of the three several states of *Peace*, of *War*, and of *Siege*, established by the law of the 10th July, 1791.

"In these instructions, are embodied the general regulations established by his majesty.

"CHAPTER I.

"*Of the preparations for defence which ought to be executed during the state of* peace, *without waiting for that of* war, *or of* siege.

"3. His majesty commands that every commandant shall consider his garrison as liable to be unexpectedly attacked, and to pass at once from a state of *peace*, to one of *war*, or of *siege;* either by rebellion, by unlawful assemblies, by the presence of an enemy, by a surprise, or by sudden assault; in a word, by unforeseen causes, of which the history of war offers too many examples.

"His majesty, therefore, directs the governor to fix, even in time of peace, his plan and arrangements for defence, according to such supposed attacks as may appear most probable, and to determine, for the principle cases that may be likely to occur, the necessary posts, reserves, and the movements of the troops; and take measures to ensure the due and active co-operation of every corps of his garrison.

" 5. He ought to endeavour particularly to make himself thoroughly acquainted with—

" First, The ground beyond the place which may be within the circle of action, of investment, and of attack:

" Secondly, The fortification of the place; its interior; its buildings; its military buildings or establishments:

" Thirdly, The garrison; the means of the place in artillery, in ammunition, and in other stores of every kind:

" Fourthly, The population to be subsisted in time of siege; the men capable of bearing arms; the master and journeymen artificers fit to be employed either on the works or in case of fire:

" Fifthly, the provisions, materials, tools, and other resources which the town itself and the surrounding country can furnish, and which it might be necessary to secure in case of a state of siege.

" In order to enable governors and commanding officers to comply with the intentions of his majesty, their principal duties, according to the circumstances in which they may find themselves placed, are detailed in these instructions.

SECTION I.

" *The reconnoissance of the fortress and its dependencies divided into three heads.*

" *Section I.—First Head.*

" *The reconnoissance of the ground outside the place.*

" 6. *The circle of action.*—The first duty of a governor, or officer commanding, from the moment of his entering upon his functions, is to study every thing which concerns the defence of the place which is confided to his care. He will therefore make himself thoroughly acquainted with its topographical situation; its connection with the neighbouring fortresses; with the frontier in general; with the offensive and defensive operations of armies, and the part it might have to play in such operations.

" He is to procure exact information respecting the roads, canals, rivers, bridges, &c., which may facilitate his communications with the neigbouring fortresses, or with any corps executing an operation in which it might be in his power to assist.

" He will cause to be reconnoitred all the debouchés, or posts, which it may be of importance to occupy before a siege, with the view of checking the march of an enemy; of falling on his convoys, or retarding in any manner his operation.

" If it should be a maritime place, he ought to know what resources for the defence can be derived from its naval means.

" He will take care to concert with the senior officer of the navy what may regard this head.

" 7. *Circle of investment.*—After having gained this preliminary knowledge, the commandant will apply himself to study, more in detail, the ground which may be included within the circle of investment, as far as the most favourable situations for the enemy's parks, and their lines of circumvallation. He will study all the undulations, in order to profit from the advantage they may offer of confining the enemy in choosing his ground of encampment. Whilst he is employed in gaining a familiar knowledge of the ground, he must calculate beforehand the way in which he could most injure an enemy, without exposing his own troops to be cut off in their retreat.

" 8. *Circle of attack.* Within the circle of attack (which extends from the glacis as far as a circle which will include, in case of siege, the enemy's depôts, and the tail of their trenches, a distance of a kilometre (nearly 1100 yards) from the crest of the parapets of the most advanced covered way), the governor, or commandant, will keep a strict watch to ensure that, in conformity to the intentions of His Majesty, no erection or establishment whatsoever shall be made which might serve as cover to the enemy.

"He will examine with attention the nature of the ground, and those parts which may be most favourable to approaches.

"9. If the place be one that has already been besieged, he must study the journal of its attack and defence on the ground itself, that he may examine what faults may have been committed in the defence, in order to avoid them; and in the attack, to the end he may profit by those of the enemy should he again be guilty of them; or in order to devise other means of opposing him, should they not occur a second time.

"10. If the fortress should possess the means of covering any of its fronts by inundations, he will make himself acquainted with the time necessary to form them: he will take care that the bâtardeaux and sluices are in a good state, and that the latter can be worked with facility.

"If it should be long since the ground formerly susceptible of inundation has been wet, and that he should be afraid lest cultivation, or other causes may have raised the land in such a manner as to render it impossible to inundate it again, he may demand authority of the minister, to ascertain this point by taking new levels: this is of the more importance, because these parts of the fortification which are covered by an inundation being always the least protected by works, it follows, that if this inundation can no longer be formed, the place will be very much exposed on that side which it ought to cover.

"If the inundation can only be formed by slow degrees, and he is afraid of an attack, he must obtain the necessary authority to commence it in sufficient time, that he may not be surprised.

" *Section I.—Second Head.*

"*The reconnoissance of the fortification.*

"11. *Of the main enclosure.*—The governor, or officer commanding, will reconnoitre, in concert with the commanding engineer, the enclosure of the fortress, the nature of its fortification and works which compose it, both as they relate to the defence in a general, and in a particular point of view: he will carefully examine whether the parapets are thick enough, and the terrepleins as broad as they ought to be for the artillery, and if the parapets are high enough to cover the men and guns: also if the scarp wall be such as to be secure against escalades, or an attack by coup-de-main; in fine, whether each of the works be capable of being retrenched, or of being otherwise improved at a small expense.

" 12. His chief attention will be directed to the points of attack, which he will study in a particular manner, that he may well understand what means to employ in order to prolong the resistance.

"13. He will order a report to be given him of the arrangements to be made for improving such parts of the fortification as are susceptible of it, and a return of those means for its execution which ought to be in readiness before hand.

" 14. *The outworks.*—After having examined the enclosure the governor will inspect all the works comprised under the denomination of *outworks*, and which are situated in the ditches of the place, such as ravelins, counterguards, tenails, &c.; he will study in what degree they aid the defence of the body of the place, and the reciprocal defence they give and receive, as well as the peculiar use which may be made of each in the general defence; he will satisfy himself that their interior is well under the fire of the body of the place, and that the communications between them, and it, are secure. His reconnoissance must include every gate, sally-port, and issue, by which he might be enabled to fall with rapidity on the enemy, whether for the purpose of preventing a passage of the ditch, or to dislodge him from an outwork which he may have gained.

"If the ditch should be a wet one, he will inform himself of the means that may exist for establishing communications between the body of the place and its outworks.

"15. *The covered way.*---The covered way will be the object of particular attention: the governor will examine whether all the branches be directed in such a manner as distinctly to see the surrounding ground; whether the traverses be in a good state; if the banquettes have the proper dimensions; if there be a sufficient number of barriers for sorties, and if they be properly disposed.

"If the communications be easy; if the places of arms which serve for assembling the troops for sallies be sufficiently spacious; if they have a redoubt or tambour to protect the retreat; in short, he will study the whole disposition, in order to understand the best destination to give the troops charged with the defence.

"16. *Advanced works*---The advanced works of a place ought to increase its capability for defence. The governor will consider for what purpose they were constructed; whether they will perform the part for which they were intended; whether their communications be secure and easy: and above all things, whether their interior be properly seen from the body of the place, or intermediate works; because in this case they present much greater difficulties to the besiegers in lodging themselves within them, and they facilitate those offensive operations of the besieged *(retours offencifs)* in which the most important part of the defence of fortresses consists.

"17. *Detached works, forts, and other dependencies of the place.*---The object of these works is in general to see into places where the undulations of the ground would otherwise give cover to the enemy; to occupy a point which commands the fortress; to protect a dyke or sluice which supports an inundation favourable to defence; or to take in reverse the approaches of the besiegers.

"The governor will ascertain the strength and nature of these works, which, for the most part abandoned to themselves, derive all their strength from their construction, and from the advantage of their position: he is not to neglect to inform himself of the different purposes for which they were erected, their comparative degrees of utility, and particularly the most speedy and effectual means of establishing their communications with the fortress, in order to have it in his power to support them, or to secure the retreat of their garrisons.

"*Section I.—Third Head.*

"*The reconnoissance of the interior of the place.*

"18. The governor or officer commanding a fortress should be thoroughly acquainted with every thing in the interior which is under his jurisdiction, or may be useful in the defence; he will observe, in conformity to the law of the 10th of July, 1791, and the imperial decree of the 24th of December, 1811, that no repairs are executed to either buildings or inclosures which may be situated on the military ground, without the especial authority of the minister at war; he will take care that the street adjoining to the ramparts remains perfectly clear for communication. In any case where the intentions of the legislature on this point do not appear to be fully executed, he may inform the minister and receive authority from him, if necessary, to enforce the proper execution of these laws.

"He will be equally careful that the streets which serve as a direct communication between the great square, or place of general parade *(place d'arme)*, as well as between the military buildings and establishments, and the street adjoining to the ramparts, shall neither be done away, nor narrowed, without the plans for the purpose having been previously concerted in conjunction with the military engineers.

"19. He will examine, with care, the site of all military buildings and establishments; the esplanades, and all other grounds connected with the fortification, to be able to judge what relation they bear to the body of the place in case of attack, or with the rest of the interior in case of alarm.

"He ought also to know the situation and capacity of such public buildings as might be converted into use, as well as what casemates and arched cover there may be, to protect the provisions, and to quarter the troops and the sick.

"20. In examining vacant spots of ground, he will come to a conclusion beforehand, as to which of them might serve for parking horses or cattle, and what kitchen gardens there may be. If places for the stowage of wood and forage will be required, he ought to sacrifice pleasure gardens for this purpose, and protect those grounds where herbs and vegetables are cultivated, as precious resources during a long siege.

"21. If water be scarce, he will cause beforehand all the wells, where it is to be found good, to be examined, that he may be able to mark them in case of siege, by putting labels outside the doors of those houses to which they belong.

"22. He will examine carefully all the water courses in the interior of the place, the bridges and sluices, the rivers, canals, aqueducts, drains, &c. in order that all the issues by which an enemy might possibly get into the place be perfectly known to him; he will see that the gratings, or other contrivances for closing them, be kept in good order, and he will, personally, take the greatest care, that none of the precautions against surprise be ever neglected.

"SECTION II.

" Divided into four heads:—of the garrison and its staff; of the artillery and ammunition; of the engineers and the materials relating to the defence; and of the siege stores.

" Section II.—First Head.

" Of the garrison and its staff.

" 23. A thorough knowledge of the place, will enable the governor to form a correct judgment of the distribution he ought to make of the garrison in the defence; to determine how the different arms should be proportioned for each operation, and the means the fortress affords for acting offensively *(pour les retours offensifs).*

" He will study the character of the different officers who compose his staff, that he may have it in his power to employ them with the greatest advantage to the service according to their talents.

" He will set them the example of punctuality in the discharge of their duty; he will endeavour by his conduct, to inspire the troops under his orders with a due respect for him; he must give them an idea of security, and never show himself anxious with regard to the weak points of his fortress.

" 24. He will exercise his garrison in defensive manœuvres. Nothing is less like the manœuvres in the field, than the more concentrated defence of fortification: it is necessary to instruct the garrison how one work defends another, and the protection the fortifications give to sorties, whether during the period of their attack, or that of their retreat.

" It is above all things important to make them well acquainted with the communications leading to the outworks, and with the successive defences of the covered-way, and intrenched works.

"The best method is to have a false attack, in which the troops of every description shall act their part, and in which every thing should be an exact representation of some particular operation of a siege: he will be merely cautious of expending his ammunition. He ought to suppose the enemy to be routed; whether through a wrong choice of the point of attack, or in causing him to attempt impracticable manœuvres, or ill-judged projects.

"He must make his men fire at the target, giving rewards as an encouragement: he will preserve memoranda of those who gained the most prizes, that he may employ them when the occasion offers. It is of consequence to fire *well* in a siege; not to fire *much*.

"*Section II.—Second Head.*

"*Of the artillery and ammunition.*

"25. The commandant will draw up, in concert with the commanding officers of artillery and engineers, the plan for arming the fortress, with the number of pieces of ordnance which may be necessary, and their stores. He is to verify the reports personally, to see that they actually agree with the state of the stores, and whether there be all the necessary laboratory compositions and other auxiliaries *(feu d'artifices)* for defending the breaches, the passages of the ditches, and for lighting and discovering the approaches of the besiegers.

"He will concert with these officers the various positions which his artillery may be made to take in the supposed attacks of an enemy: and he will also determine on the means to be employed to cover it from their fire.*

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* General Gribeauval, in 1770, proposed that the calibre of guns mounted on the ramparts of a fortress should be reduced to about

"*Section II.—Third Head.*

"*Of the engineers, and the materials relating to the defence.*

"26. The governor will examine, in concert with the commanding engineer, the state of the storehouses and materials for the fortifications. He will acquaint himself whether there be in the fortress palisades in sufficient quantity to replace such as may be destroyed: whether there be a sufficient quantity of gabions, fascines, hurdles, beams, planks, round timber, cordage, iron, intrenching tools, mining and carpenters' tools, nails, chevaux de frize, in short every thing that is requisite for defence.

"*Section II.—Fourth Head.*

"*Of the provisions and the other matters belonging to the commissariat.*

"27. The governor will examine into every thing which may concern the subsistence and the health of the garrison and the inhabitants: he will cause reports to be made to him of the grain, the meat, and liquor of every description, which he will personally verify: the description and state of preservation of the ovens will be inspected, to be assured that they will suffice for the garrison.

"28. The quantity and quality of provisions of every description ought to be perfectly known to him; in order that, calculating the force of the garrison and the wants of the place, he may take the necessary measures for keeping them complete,

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18-pounders, as it is not extreme range, but multiplied fire, that is most required for the defence; and that this calibre is quite sufficient to batter parapets newly made, heads of saps, &c. He also recommends light elevated carriages, that the guns may be readily moved from place to place.—*C.*

or for sparing them in order to prolong the defence as much as possible, in case circumstances should not have allowed him to lay in all that may be proper.

"29. He will visit the magazines of provisions, that he may know whether every thing relating to them be well regulated, and each species of provisions be stowed in the most appropriate place. Looking forward to the necessity of placing them in security in case of siege, should the town not contain a sufficient number of casemates, he will take an account of all the buildings, and particularly of cellars which may serve this purpose; in order, if required, to render them proof against the projectiles of the enemy. This precaution should extend to all the stores and provisions for the siege, to whatever service they may belong; and a fair division should be made of the bomb-proofs, according to the real wants of each branch of the service, and not to demands often exaggerated.

"30. The hospital merits very serious attention; the governor should examine whether it admits of being blinded,* *(blindé)* and if it would be sufficient for the necessities of the garrison during a siege. In case it would not, the governor will fix on one or more large and commodious buildings for the purpose, in order to cause the necessary work to be commenced for the security of the sick, from the moment the place may be threatened.

"SECTION III.

"Divided into two heads:---of the population, and of the resources which the town and environs may furnish.

"Section III.---First Head.

"The census of the place: of the useful hands and the useless mouths.

"31. The governor ought to make himself acquainted with the character and disposition of the inhabitants, particularly if

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" * Converted into a temporary bomb-proof by strong timbers.

the fortress should have been a recent conquest, in order to restrain or send away the mal-contents who may be in it.

"In the French fortresses the governor may organize the national guard, which will be a great resource. By animating and encouraging them they will become inured to danger like the troops of the line.

"In a place that has been recently conquered or united, it will be more difficult to derive assistance from the inhabitants; but if the governor knows how to make himself respected; if he has given convincing proofs to the inhabitants of his justice and his firmness, he will at least have nothing to fear from them, and rewards or severe punishments properly applied, will maintain them in their allegiance.

"He ought, beforehand, to cause the mayor to furnish him with correct returns of the population, and the resources of the town, in order that he may form his calculations of the numbers to be maintained in case of siege; also returns of all useless mouths to be sent away; of men fit to bear arms and of master and journeymen artificers fit to be employed in case of fire or on the works.

" *Section III.—Second Head.*

" *Returns of stores and materials: of provisions; and of arrangements to prevent fire.*

" 32. The governor will cause returns to be made of every thing useful in case of siege, whether it be in the town or in the surrounding country, that he may be enabled, at the moment of need, to collect whatever may benefit the defence, and to destroy whatever may be hurtful to it by falling into the hands of the enemy.

" 33. He will cause the inhabitants who ought to remain in the fortress, to provision themselves in due time, for a period at least as long as that for which the garrison is provisioned: he must make them understand the necessity of not waiting till the last moment, for supplying themselves with the things they require for their consumption, because they ought to know that their interest, in this respect, is the same with that of the defenders, and that those who are herein guilty of neglect, will run the risk of want during the siege, or of being turned out as useless mouths.

"34. One of the most important cares of the governor will be to make arrangements beforehand against fire; for this purpose he will concert with the civil authorities, in order that they may form squads of firemen, purchase fire engines, ladders, and hooks, and that they may oblige the inhabitants, according to their means, to provide a certain number of leather buckets, and to furnish themselves with tubs for holding water. Such an organization for a fortified place, provided it be well executed, will give great security to the inhabitants against fire, which either the enemy, or the ill-will of any of the people of the town, might occasion.

"CHAPTER II.

"*Of those preparations for defence which belong to the state of war, and especially on the prospect of a siege.*

"35. The moment a place is declared in a state of war, the governor will redouble his vigilance and activity, in order to execute all those measures of defence which a perfect knowledge of his fortress, and its resources, may have made him judge necessary. From this period, both the national and municipal guards are under his command; and the civil authorities can neither issue any police regulations, except in concert with him, nor can they refuse to promulgate those, which he may deem necessary for the security of the place, or for public tranquillity.

"36. The governor will accelerate the works of defence, by every means in his power.

"37. He ought now to commence the inundations, if they are slow in forming themselves, and to fill the reservoirs which are to sweep those ditches which ought at first to be defended as dry ditches.

"38. He should construct bridges of rafts, to communicate across ditches and rivers: such bridges cannot be destroyed by the enemy's artillery, and will bear the heaviest weights.

"39. In sea ports and in fortresses situated on great rivers, or fortresses, in front of which wide and deep inundations may be formed, he will collect armed boats. The mode of arming them must be concerted with the commanding officers of the artillery and engineers, and when there may be one, with the senior officer of the navy.

"40. The governor will apply himself, with the greatest diligence, to all that regards the provisions and stores of every species, and he will use all means to make them complete and to keep them so: this is the most delicate part of his duty and that in which negligence might cause the worst consequences.

"If all the grain be not ground, he will cause it to be done, or else satisfy himself that there is the means for grinding it during the siege, by constructing in time either hand-mills, or mills to work by means of horses.

"41. Great fortresses alone have the property of having some part of the interior little exposed to the enemy's fire: such an advantage is precious. It is in those parts that it is of consequence to deposit such provisions and stores as are most valuable, avoiding however to unite them in mass that they may not form a focus for conflagration.

"Magazines of wood and forage ought to be in the open air, in small isolated stacks. The daily issues can be very well made in sheds.

"42. When the town is small, and where there is no quarter that will not be very much exposed to the effect of the enemy's projectiles, the bomb-proof covers must be multiplied as much as possible by means of blinds (*blindage*). Such shelter is formed in a short time, and only requires timber and earth. Buildings having brick walls may be advantageously used for the purpose; they should be blinded on each story if possible, the useless doors and windows should be blocked up, and in this way healthy bomb-proof cover may be obtained for the defenders, and especially for the sick.

" 43. If there should be neither building fit for blinding, nor yet bomb-proofs in a fortress, their place may be supplied by forming blinds, of trees leaning against each other in a sloping position, or by placing them reclined against revêtements or solid walls, in those parts which are the least exposed.

" 44. The same measures should be adopted for the powder magazines if they are not already bomb-proof. Such as exist ought to be solidly blinded, and if they should not suffice, then dry cellars must be occupied and blinded.

" 45. The wells and cisterns which may be necessary for a supply of water must be also blinded.*

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* The insufficiency of blinded cover as a protection against the increased effects of mortar and howitzer fire, has been already mentioned in paragraph 205; and is still further illustrated by the following remarks extracted from the History of the Siege of Antwerp in 1832; published in *the United Service Journal. No. 52.*

3d to 4th December, 1832.—" Generally speaking, the blinds raised over the embrasures on the faces and salients of the citadel, from being exposed to a raking fire, especially from the long howitzers, were seen to give way, and may be said to have produced embarrassment rather than security.

"General Chassé, in his report dated 10th December, says, The enemy employed against us pieces of a new invention, called Paixhans, (i. e. long howitzers). Nothing could resist their force, which causes great ravages in the buildings and blindages."

" During the day (6th December) the buildings of the citadel were observed to be on fire in various quarters, whence large columns of smoke and bursts of flame were seen to ascend. Towards dusk, the grand magazine of provisions, which had been carefully blinded, was ignited, and burned with such fury as to baffle all efforts to arrest its progress. The temporary bomb-proof hospital, also rendered as secure as the

"46. After these details it will be seen how necessary timber is in a fortress. Therefore the governor must neglect no means of augmenting his store of that useful article. It is also

nature of such works admit, was traversed by a shell, and three men killed. The insecurity of this building was so great that the wounded were removed to the Tête de Flandre."

Again, "from 7th to 8th of December. A howitzer shell from battery No. 4, having penetrated the blindage of the laboratory, set fire to the loaded bombs and other combustibles deposited there, and caused considerable havoc. The utter inefficiency of these temporary casemates against the plunging fire of the new model howitzers, or indeed against that of mortars projected at the usual elevation, began to awaken serious apprehension in the mind of the governor, and was a source of deep anxiety to himself and his officers, who saw the most important points of shelter thus hourly menaced with ruin, without the possibility of applying any remedy.

" Many passages in General Chassé's report, not only dwell on the sufferings, but plainly indicate the fatal moral effect wrought on his people by the scene of devastation that surrounded them, and thus shows the paramount importance of airy, extensive, and secure bomb-proofs."

During this siege, from the continual shower of hollow projectiles from the French batteries of attack, the defenders of the citadel had "no repose, no efficient mode of cooking; they had lost all confidence in the protection of their shelter; were harassed day and night by the fall of buildings; were herded beneath posterns, insecure blindages, cellars, damp casemates, and infected communications.

"From 8th to 9th December.—On the previous day heavy jets of smoke and flame were seen to rise from the great barracks, the upper story of which had been filled with earth, manure, and other precautions against fire; but by the afternoon of the 8th, the whole was reduced to a heap of ashes.

"The loss and inconvenience inflicted on the besieged by this misfortune, was an aggravation of their suffering. For now the laboratory, kitchens, church, hospital, and magazines of stores and forage; in short, almost every building in the place was destroyed, or so riddled with shot, as to render it unsafe to approach their crumbling walls; and thus forced the soldiers not on duty to confine themselves to posterns and casemates."

The wells, also, from want of proper bomb-proof cover were so greatly injured, that the defenders were much distressed for wholesome water.

required for retrenchments, for tambours in wood, for fraises and palisades, for repairing damaged gun carriages, for constructing rafts, &c. and for the consumption of the garrison.*

"47. The firemen, if there be any, with their engines and articles belonging to them, now also pass under the command of the governor. He will, in concert with the civil authorities and commanding engineer, regulate their duties in case of fire during a siege.

"He will equally instruct the inhabitants what they have to do, whether it be with regard to fire, in securing their cellars, or in forming shelter, by constructing small blinds out of the remains of houses, which the shells may have knocked down.

"48. Should the enemy approach within less than three days' march of the place before it be declared in a state of siege; or should the minister, or the commander of the forces give the order, then the governor, invested with the necessary authority, must cause all useless mouths, all foreigners, and persons suspected either by the civil or military police, to quit the town: he must bring in, or prevent from going out, all artificers and materials, cattle, goods, and provisions. He must also

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As a proof also of the efficiency of good masonry casemates, it is stated that on the 21st of December, (sixteen days after the batteries of attack had opened), notwithstanding the incessant discharge of one hundred and thirty pieces of ordnance, not a single casemate in masonry had received any serious damage.—*C.*

* The advantage arising from planting the ramparts and open spaces within fortresses has been always admitted, and yet it is not always practised. An order was issued in 1795 to plant the glacis of every French fortress with trees, for reasons which are given at length in the 155th paragraph of St. Paul's Traité Complet.—*T.*

" At the siege of San Sebastian, when attacked by the English in 1813, the trunk of a large poplar tree completely stopped the progress of the sappers, and defied all their efforts to move it, until one of them gallantly jumped from the trench, and stood exposed until he moved it from the head of the sap, and returned without being wounded.—*T.*

species of ordnance of all calibres should be well understood, in order to determine in what way they shall be employed during the various circumstances which arise in a siege.

"Above all, the very oblique fire *(feu d'echarpe)* must not be neglected, by establishing batteries on those works which are collateral to the front of attack.

"55. When the siege is about to commence, the governor is to neglect no measure which may enable his fortress to make the longest possible defence.

"He will seize those avenues and positions, in advance of the place, which are the most capable of being defended, and from which the retreat is easy.

"56. When circumstances admit of it, he will send out parties, to communicate with those detached from the neighbouring fortresses, and to skirmish with the enemy; by which means he will accustom his garrison to war, and to act offensively. He will regulate his conduct in sending out these small detachments by the imperial decree dated 24th December 1811, article 99, which directs that these parties be compesed of a number so small that their loss may not materially diminish the force of the garrison. He will not send them beyond the circle of investment, excepting to make a reconnoisance which may be of importance to the safety of the place.

"57. In the interior he will establish good order in every branch, and he will be particularly watchful that the provisions be distributed in a just proportion to what may be required: and if the fortress should not be completely provisioned, he will economize the subsistance, so that he may be able to make a resistance which shall be in proportion to his means when judiciously husbanded. A few days added to the term of defence might give time for unexpected succours to arrive, and even to oblige the enemy to raise the siege; whereas on the other hand the place might be forced to surrender, should the governor, by consuming his resources too soon, had put it out of his own power to prolong his defence to the last extremity.

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" CHAPTER III.

" *Of the state of siege.*

" *Section I.*

" *Divided into five heads: and treating of irregular attack, which may place a fortress suddenly in a state of siege.*

" *First Head.*

" 58. *Of surprises by the enemy, or by revolted inhabitants.* The governor, responsible for the place confided to his care, ought to neglect nothing to prevent surprises, and should take the most minute precautions against their occurrence. The following measures should be adopted: to repair every part of the rampart by which an enemy might insinuate himself into the place; putting double gratings to the drains, or aqueducts, and placing sentries to watch them; and always to have at hand at the point of danger, detachments which may be brought up rapidly. He should likewise shut up all the embrasures or openings that may be too low.

" 59. If there should be no drawbridges in front of the gates, palisades or advanced barriers should be constructed, and warders posted in them, for the purpose of stopping strangers and examining waggons.

" All openings caused by rivers should be shut in a similar manner, and all boats carefully searched.

" Before the gates are opened, some soldiers should patrole to all places where an enemy could conceal himself.

" Persons waiting at the gates for admittance should be examined; loaded waggons should be forced to keep off to a distance, and should be probed; the second gate should not be opened until the first is closed and the drawbridge raised; the guard should be under arms inside the gate; waggons should be admitted only one by one, and never be suffered to halt between the gates; care should be taken that the portcullis be in a proper working state, (if one exist) and that the mode of using it be explained by the old guard to the new, at the time of relief.

" 60. Patroles should be made to prevent such assemblies as might be dangerous.

" In holidays and days of rejoicing the guards should be doubled, and the country scoured by cavalry patroles.

" At all times detachments should patrole the neighbourhood in the day, and still more particularly in the night.

" 61. Firing during the night is to be expressly forbidden, neither is any fire to be made which may be seen from the country, nor are fireworks allowed to be burnt.

" 62. The sentinels are to be kept on the alert by frequent rounds, and care must be taken that they are properly posted.

" 63. Mortars, loaded with light balls, must be ready, that they may be thrown on the glacis on the first indications of any attempt by the enemy.

" 64. In time of frost the ice in the ditch must be broken every day. In such a case, when a channel has been made in the middle of the ice, a boat should be continually dragged up and down, which, by its motion, will prevent it connecting itself again.

" 65. In foggy weather the precautions should be doubled; the approaches to the counterscarp watched, by posting a sufficient number of sentinels and small parties in the covered way, so as to prevent an enemy's being able to pass between two of them, and to enter it without being seen.

" 66. If the governor be watchful that the service be performed with exactness; if to all the precautions pointed out, he add those which a knowledge of the fortress may suggest to him, particularly if he have been able to obtain exact information of the different movements and designs of the enemy, he will undoubtedly be secure against all surprise from the exterior.

"67. To protect himself against revolts in the interior, he must establish a severe police, and study well the character of the inhabitants; and if he has reason to fear them, they must be disarmed: and he must take measures of precaution in time, such as to fortify the guard-houses against the town, to have artillery ready to occupy all the streets leading to the spots most favourable for large assemblies, and to secure the avenues of the citadel or keep, in which the service must be performed in the strictest manner to prevent surprises.

"If they should come to open sedition, he must instantly order the whole garrison under arms; he will re-inforce the posts; increase the patroles that they may disperse assemblies, and during the first moments he should principally employ cavalry: he will then cause the entrances to all the principal streets to be strongly occupied, so that, should the revolt become of too serious a nature, and the garrison be too weak to keep the multitude in check, they will have it in their power to retire in good order into the citadel, from whence he will threaten to destroy the town, if the inhabitants do not return to their duty; but he ought previously to have made arrangements for spiking all the guns before he evacuates the town, in order that the seditious may not be able to use them against himself.

"68. With firm conduct and great watchfulness, a governor has little to fear from revolt; but if he cannot prevent it, he ought to set every means to work to tranquillize it; and the most severe measures ought to be used towards the guilty, if after having employed mildness and persuasion they persist in the rebellion.

" *Section I.—Second Head.*

"69. *Of escalades.*—Every thing which has been stated in the preceding paragraph relating to surprise applies to this, because, if proper precautions have been taken, it will be difficult, if not impossible, for the enemy to get into the ditches of the place and to plant ladders without being discovered, or without the garrison having timely notice of the design, and being in a state to defeat it.

"70. If the garrison should be so weak as not to be able to watch the exterior with all the vigilance required, the following precautions may render null any attempt of the enemy.

"They consist in cutting a cunette in the ditch, and there planting a row of palisades at some distance from the wall, so as to prevent ladders being applied to it; in covering the ditch with crows' feet, and in digging pits or small ditches and covering them with hurdles and earth:

"Also in placing on such portions of the parapet as the garrison may not be able to occupy, chevaux de frize and other obstacles to prevent the enemy from gaining the ramparts.

"71. Halberds, scythe blades attached to long handles, pitchforks, and such other arms as are proper for repelling the enemy when he gets to the top of the ladders, should be placed in the guard-rooms adjoining to the ramparts, which should be covered with beams to roll upon the ladders and to crush them.

"The flanks should be provided with guns loaded with case-shot.

"Lastly, the ditch should be illuminated by means of light balls,* so that the cannon of the fortress may produce a great effect against the troops who shall have entered it.

"72. But the most essential point, and it cannot be too often repeated, is that the duty should be done with punctuality; for the enemy knowing that a garrison is watchful, will not attempt a hazardous expedition, the preparations for which he cannot conceal from a vigilant governor, and one who knows how to keep up useful communications with the exterior.

"* The simplest light balls are made by filling common shells, or grenades, with a mixture of sulphur and nitre.—*T.*"

" *Section I.—Third Head.*

" 73. *Of attacks by sudden assault.* Attacks by sudden assault, or accelerated sieges *(siege brusqués)* are, properly speaking, a species of surprise against which the vigilance and precaution recommended in the preceding paragraphs are the most effectual preservatives. Nevertheless it may happen that the enemy, pretending to besiege the place regularly, may attempt to accelerate the approaches against one of the fronts of the fortress; it is necessary in such a case to fall upon him vigorously, and to leave nothing undone to drive him from the works of which he may have taken possession.

" 74. One may suspect his intention if he does not make his attack on that side of the place where he ought naturally to do so, in order to take it in the easiest way.

" In such case, the guard on that side ought to be doubled.

" 75. In general it should be considered necessary to watch every front of the fortress. Even when it is evident, from the works of the enemy, which is his point of attack, the other sides must not be neglected: but it becomes more particularly so, when there is a point which is admitted to be accessible, that it is of importance to take every precaution against sudden assault, and to do all that is possible beforehand to render it secure.

" *Section I.—Fourth Head.*

" 76. *Of bombardments.* Simple or irregular bombardment may be either effected by a corps of an army, which is too weak to invest a place, planting mortars hastily opposite to one of its fronts, or by bomb-ships if the place be a sea port.* The

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" * The system of applying gun locks to mortars on board of bomb-ships has made their fire much more accurate, and that, added to the great improvements in the stowage and in preparing the ammunition and shells for action, has rendered them much more formidable and important than they ever were before.—*T.*"

governor ought in such case to try and destroy the land batteries by sorties or to burn the squadron. In either case he should multiply the number of guns on the faces which see the line of the enemy's fire.

"77. As such an attack leaves room for introducing succours into the town, there can be no reason for sparing the ammunition.

"78. Nevertheless the governor should cause the ammunition and provisions to be placed in casemates, or under bomb-proof blinds; or at least to place them in the parts of the town the least exposed to the enemy's fire.

"79. He ought to establish measures for maintaining tranquillity amongst the inhabitants, and to take every precaution against fire. A well arranged organization renders the effect of incendiary projectiles almost null; sentinels taken from the companies of fireman (*pompiers et garde-feu) watch the fall of shells or the direction of red-hot shot; those on guard, furnished with buckets, run to the spots where fire shows itself, and put it out at its commencement. They follow the red-hot shot, throw water into the holes which they have made, seize hold of them with pincers and carry them away in metal spoons, or vessels, to the nearest reservoir of water. By following this system, there is no reason to fear extensive fires breaking out; and as the inhabitants themselves are interested in establishing the strictest watch, the enemy will not succeed in destroying the town, and he will have consumed his ammunition in vain. All examples prove that this mode of attacking places, at the same time that it does not destroy the fortifications, causes little loss to the besieged.

Section I.—Fifth Head.

"80. *Of Blockades.*—It sometimes happens that the enemy being unprovided with the means required for under-

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" * In France they have a military organization.

taking all the works of a siege, and supposing the place to be badly provisioned, he confines himself to closely blockading it, by seizing all the avenues, in order to prevent the arrival of any succour, and to force it to surrender by famine.

"The dispositions to be made in this case are, to send away all useless mouths; to cause all the means of subsistence, which the environs of the place may furnish, to be brought into the town; to use the strictest economy in the distribution of provisions, and to watch the consumption of those of the inhabitants, that they may make them serve whilst the fortress holds out to the last extremity.

"82. If, to a blockade the enemy should join a bombardment, the precautions recommended in the preceding paragraph against fire, and for the security of the provisions and ammunition, ought to be made use of. As to the defence, in these two cases, it should be made in the exterior.

"83. In keeping the field as long as possible; in disputing, inch by inch, all the positions proper for the establishment of the enemy's batteries; in continually harassing his working parties; in destroying every thing which may afford him cover, the garrison will protract the period of the investment or bombardment, and consequently the capture of the place. It is for the governor to judge when sorties are to be undertaken, or when petty war is to be carried on, that the losses he might sustain may not influence the fate of the place.

"*Section II. divided into four Heads.*

"*Of Sieges, or Regular Attacks.*

Section II.—First Head.

"84. *From the period of investment to the opening of the trenches.—Lines of circumvallation, countervallation, &c.*—The presence of an enemy's army within three days' march of a fortress, places it in a state of siege, in conformity to the imperial decree of the 24th of December, 1811, article 95. The governor being previously informed of the projects of the enemy, ought to have every thing prepared for resisting a regular attack as long as possible. The remainder of these instructions will only develope the general rules of defence, and trace the path to be followed in order to obtain the *maximum* of resistance, which point every governor who is sensible of the importance of his charge, or who wishes to prove himself worthy of the confidence of his sovereign, ought to reach.

"85. As soon as the enemy approaches to invest the place, the governor finishes his first preparations with all possible activity; he occupies such advanced posts as may have their communications with the fortress secure; he sends patroles in every direction to get information of the enemy's movements, and to find out as well as they can his force, his projects, and his means of executing them.

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"88. Whilst the besiegers are at work on their circumvallation, the governor either should not fire, or he ought to deceive them in the range of his artillery, by firing with half charges. By acting thus, either the enemy may extend his line of circumvallation considerably, which will make it more difficult to guard, or else he may bring it too near to the place, so that the cannon of the fortress being able to reach his camp, he will be forced to move it, and re-commence his line of circumvallation.

"89. The investment being effected, the enemy's camp will be drawn on the plan of the place, according to which the governor, in concert with the commanding officers of artillery and engineers, will regulate his arrangements for the defence, in proportion to the enemy's progress.

"90. If the garrison be strong, some sorties may be hazarded; but it is seldom that sorties at such a distance succeed, unless it be in consequence of the fault of the besiegers in neglecting the ordinary precautions. They are besides very fatiguing for the garrison, which it is more advantageous to employ, in executing the pressing works always required in a defence.

"91. At night he will send out small parties in opposite directions, who will creep along, taking advantage of banks or uneven ground, and proceed in silence as far in advance as possible; then lying flat on the ground they will listen with attention to the smallest noise; they will afterwards retire on the fortress in extended but connected order, to try to surprise officers who may be in advance to reconnoitre the place. These parties must agree on a signal that they may know each other.

"92. In the first moments, the governor may employ his good marksmen advantageously; he ought to arm them with wall pieces and place them in the most elevated situations, and he should mix some of them with the parties sent outside the place, with orders to fire on those who may be attempting to reconnoitre the fortress.

"It is at night fall that these marksmen ought to watch, with the greatest attention; that is the period for reconnoitring, tracing, and pushing forward the attacks.

Section II.—Second Head.

"93. *From the opening the trenches to the crowning of the covered way.*—As soon as it is known in what direction the enemy is opening the trenches, the governor causes embrasures to be opened, and platforms to be laid for the guns; double rows of palisades to be planted in the covered way; useful temporary works of fortification to be made, such as flèches at the foot of the salient angles of the glacis; these flèches, made capable of resisting a coup-de-main, retard considerably (as is well known) the commencement of the third period of the siege, which is the most important: he causes mines under the glacis to be prepared with diligence; bridges of communication to be promptly established, for which timber ought to have been prepared beforehand and placed in store, and he causes the retrenchments of the outworks, and of the bastions, to proceed with the greatest activity. If these retrenchments are not ready made, and have not revêted scarps, they should be as solid as earth and fascines can make them, and according to plans which should be well digested long before.

"The same applies to redoubts in the salient and re-entering places of arms.

"94. If there be no caponieres communicating between the place and its outworks, the governor should cause them to be made.

"95. When the enemy shall have forced the out-posts to fall back, the governor ought to keep his garrison as much as possible behind the advanced works, and to preserve for himself as long as he can, the attitude and energy of the offensive. The garrison posted thus, is in the best possible condition for sorties, which ought to be multiplied but with prudence.

"They should be at one time great sorties, at another time petty ones; sometimes false, and often real.

"The governor's object ought to be to torment and harass the enemy, and to keep him continually on the alarm, which will cause him to lose as many men by fatigue as by fighting.

"Sorties have always the effect of interrupting the enemy's works, and of dispersing the workmen. In the confusion and obscurity of night it is difficult to assemble them again and to set them to work.

"In real sorties there should always be working parties to destroy and fill in the trenches, and some draft horses to carry off cannon which may be taken.

"96. At this period of the siege there ought to be little firing, that the gunpowder may not be uselessly expended.

"Besides, cannon fired with full charges produce little effect against the parapets, or the earth of the trenches which rolls to its natural slope.

"But if any branch be exposed to ricochet and enfilade, the besieged should fire the more, and inundate those trenches with grenades and shells.

"97. As the works of the enemy advance, the governor ought to endeavour to outflank the attacks, either by armed boats (in places situated on rivers or on the sea), or by pushing out lines of counter approach.

"These lines are a species of trenches which run out from the covered way on the right and left of the attacks, to enfilade the works of the enemy. They ought to be applied with circumspection. Destined to outflank the enemy's trenches, they should neither be plunged into, nor enfilade themselves. They ought therefore to be adapted to the nature of the ground, in such a manner that their prolongation shall fall in hollows, rivers, ravines, or in marshes, beyond which cannon could no longer act against them with effect, and that they shall terminate, if possible, upon some inaccessible piece of ground, that the enemy may not have it in his power to cut them across by a boyau from his trenches, or to envelope them in an attack.

"98. Good marksmen may also be sent out a little before day-break, who should place themselves flat upon the ground on the prolongation of the advanced branches, and who, as the day breaks, should retire into the covered way, after having kept up a deadly fire on these branches, in which they will cause great disorder. If there be any light artillery, some pieces of small calibre may also sometimes join these marksmen.

"99. Whilst the attack advances, the governor adds by every possible means to the defences of the front attacked. He completes the retrenchments in the bastions, and the cuts in the outworks.

"100. He ought to neglect nothing which would animate the *moral* of the soldier and augment his energy. He should make the most of the smallest success, spread advantageous reports, and distribute rewards and honours; but the governor should above all things, by his own example, keep up the confidence of his soldiers.

"101. When, in spite of the efforts of the besieged to retard the advance of the attack, the enemy shall have arrived on the glacis, the governor will employ all the resources of subterraneous warfare, which may either form part of the fortifications, or which he may himself have contrived.

"A well directed fire crushes the heads of saps; the marksmen posted in the covered way retard the progress of the works; small sorties upset them.

"At such moments the artillery of the fortress must be ready to fire against all who show themselves in repulsing these sorties.

"102. Whenever the enemy may have blown up any part of the trenches, the besieged should take advantage of the disorder of the enemy, and upset as much as they can of his works. From their branches, prepared beforehand, they may easily discover those of the enemy, and crush or suffocate their miners.*

"103. If the besiegers decide to assault the covered way, the salient parts, which are under the protection of the fortress and its outworks, should be defended as long as possible.

"104. If the enemy be most decidedly superior, the salients should be abandoned to him, and the re-entering places of arms firmly maintained. The enemy should be left for a while exposed to shells, grenades, and stones; after which the besieged should debouche from the re-entering places of arms, not only of the fronts attacked, but from the adjacent fronts, to drive back the enemy and to destroy his lodgments.

"105. If he decide on crowning the glacis step by step, the progress of his saps becomes slow and deadly: in order to drive the defenders from the salients, he must construct trench cavaliers, the formation of which is long and perilous, or

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"* This may apply to besiegers without sufficient means of attack; but with proper means, and a properly organized engineer department, the system of attack in mining is decidedly superior to that of the defence, unless it be as far as regards those mines constructed under the ditches and the breaches.—*T.*"

powerful batteries which are difficult to erect, under the close fire of the place; after which in carrying his lodgment along the crest of the glacis, he must successively drive the besieged from each traverse: master of the branches, he has to attack the re-entering places of arms and their redoubts; and it is only by sacrificing a number of men, and by surrounding himself with traverses, that he can protect himself from the reverse fire of the outworks, and make himself master of the covered way.

" 106. It is during the attack and after the capture of the covered way that the governor ought to multiply the quantity of shells, grenades, and stones to be thrown into the enemy's lodgments: these projectiles have their full effect in a close defence, and disperse the enemy, who, crowded within his lodgments, has no means of securing himself.

" *Section II.—Third Head.*

" 107. *From the crowning the covered way, until the assault.*—After the capture of the covered way, the besiegers endeavour to establish their breaching batteries: their construction is retarded by deadly projectiles: they are counter-battered by very oblique batteries *(en écharpe)* which force them to the construction of reverse traverses.

" 108. The breach being made in the ravelin, the enemy commences his passage of the ditch; he must make epaulements, or if the ditch be full of water, he must make a bridge of fascines to arrive at the work; the besieged oppose this dangerous operation by all the means which are left them; they overthrow the bridge and the epaulements by their batteries, disperse the workmen by their stone mortars, their howitzers, and their hand grenades; and (if they have any) they bring forward their armed boats, until this period kept behind the tenails, to open a destructive fire on the passage of the ditch.

" 109. If the nature and construction of the sluices will admit of it, they suddenly open them, overthrow the bridge, and sweep it away.

"110. If the ditches be dry, they assemble sorties behind their caponieres and tenails, march rapidly on the works of the passage of the ditch, and with hooks drag down whatever it may be composed of, hastily setting fire to the fascines or other combustible materials of which it may be formed.

"111. The governor endeavours to clear the breach as it is made, in order to render it less practicable; he prepares fougasses under it; he buries shells and boxes of combustibles in it; he then forms abbatis, plants palisades, chevaux de frize, and prepares vigorously to dispute it with the besieger when he shall assault it. Here the whole energy of the besieged should be displayed. They have no longer to withstand the whole of the enemy's artillery, which must cease firing on the breach, when the besiegers are ascending it, whilst their own fires incessantly upon the narrow defile by which the assailants arrive at it.

"112. It is for the governor firmly to convince his garrison, that the most dangerous operation for the besiegers, and that most likely to cause his defeat, is the assault.

"113. Such are the obstacles the enemy ought to meet with, in possessing himself of the breach of the ravelin, which he may besides find defended by a cut yet to be disputed. If this ravelin has a redoubt, a new operation has to be commenced, a new breach made, a new passage of the ditch and another assault to be given: for a governor cannot be supposed to give up a work without having defended it to the last extremity.

"114. Master of the outworks at the expence of so much time and blood, the enemy has immediately to re-commence a new and more dangerous attack against the body of the place, to make a passage of the ditch longer than the former, more bloody, and easier to be destroyed.

"115. The governor must have some resolute men to clear the earth from the trenches; this operation retards the assault, which can only be given when they are practicable.

"116. With a garrison which is well disposed, a governor may undertake works of the most extensive nature during a siege, and even under the enemy's fire.

"117. After having long disputed the passage of the ditch, he must stand the assault of the body of the place.

"He bristles the breach with the last obstacles he can collect; he improves the retrenchments in the interior: the smallest parapet; the houses at the foot of the rampart; even the ruins of these houses may be transformed into retrenchments, from behind which, hand grenades, small shells, and stones, may be hurled upon the enemy, and oblige him many times to renew assaults so deadly for him.

"118. During the whole period of the siege, and particularly towards the latter part of it, the governor will exercise the strictest watch to repress the murmurs of the inhabitants, and to prevent them from influencing the soldiers. He must stifle every murmur by an inflexible severity. He must never forget that to him is intrusted one of the bulwarks of the empire: one of the points of support for an army; and that its surrender accelerated or retarded by one single day, may be of the last importance in the defence of the state, or for the safety of an army.

"119. He must, in consequence, be deaf to all reports spread by the enemy, or which may come to him directly, or indirectly. Even if they would persuade him that our armies are beaten and France invaded, he must neither suffer his own courage nor that of his garrison to be shaken. This, in a few words, is the rule of conduct prescribed by his majesty in his decree of the 24th of December, 1811.

"120. It becomes therefore the governor's duty to make use of every effort to defend the place to the last extremity; and it is not until he shall have expended every resource, and when it shall be out of his power to repair his last retrenchments, on the point of falling, that he may consent to surrender.

CHAPTER XI.

On field fortification.

305. "In a war of march and manœuvre, if you would avoid a battle with a superior army, it is necessary *to entrench* every night, and occupy a good defensive position. Those natural positions which are ordinarily met with, are not sufficient to protect an army against superior numbers without recourse to art.

"Those who proscribe lines of circumvallation and all the assistance which the science of the engineer can afford, deprive themselves gratuitously of an auxiliary, which is never injurious, almost always useful and often indispensable. It must be admitted at the same time, that the principles of field-fortification require improvement. This important branch of the art of war has made no progress since the time of the ancients. It is even inferior at this day to what it was two thousand years ago. Engineer officers should be encouraged in bringing this branch of their art to perfection, and in placing it upon a level with the rest." *Military Maxims of Napoleon.*

Napoleon acted on these sentiments whenever he had an opportunity and time for stengthening himself by field works: for instance it is known that at the battle of Austerlitz, where the contending armies were nearly equal, he rose early in the morning to superintend and stimulate the construction of retrenchments.

In the records of the wars between Prussia and Austria, Frederick II. and Marshal Daun, (the respective leaders of their armies) invariably strengthened themselves by the construction of redoubts and field works; they were greatly used by Marshal Saxe and by Marlborough. A few redoubts saved Peter the

Great, at Pultawa, and enabled him to gain a victory over his hitherto successful foe, Charles XII.: and at the battle of Borodino, (fought on the 7th. September, 1812, between one hundred thousand French and one hundred and forty thousand Russians) a few slight open field works caused the French a great loss, and nearly proved fatal to the further advance of Napoleon: and lastly, the Duke of Wellington highly esteemed every means of the kind that could strengthen his position, as is found by attending to his defensive campaigns; the most splendid instance of which, was the construction of the lines of Torres Vedras.

306. Sir John Jones in his war in Spain, in speaking of Bonaparte's preparations for the conquest of Portugal in May 1810, at page 115 states that "three corps commanded by Marshals Ney and Junot, and general Reynier, composing an army of sixty-six thousand infantry and six thousand cavalry, were united for that purpose near Salamanca; and Marshal Massena, heretofore considered the boldest and most fortunate of Bonaparte's lieutenants, was sent from France to direct the enterprise. To give further importance to the operation, a strong body of the imperial guard crossed the Pyrenees, and the remainder was held in readiness for the same destination.

"The army collected to oppose this threatened invasion did not exceed forty-eight thousand infantry and three thousand cavalry; the half of it composed of young Portuguese levees, yet untried in a general action, of which a very unfavourable judgment continued to be entertained, notwithstanding the numerous proofs of courage they had lately evinced in various slight encounters. To give them steadiness and confidence, the troops of the two nations were now brigaded together in the proportion of one Portuguese to two British battalions: and even beyond this support, the foresight of Lord Wellington had provided a further auxiliary to compensate their little experience. Anticipating the awful crisis now arrived, and resolved not to commit his army in action, except under very favourable circumstances, he had, as far back as the previous October, caused a position covering Lisbon to be strongly retrenched, with the intention, on the advance of the invading force, to retire upon it, and there decide the fate of the Peninsula: notwithstanding the magnitude of the work, no account of its progress ever became public, and the invaders remained ignorant of the formidable nature of the barrier which had been raised against them, till they found the allied army arrayed on it, to stop their further advance."

Before reaching this strong retrenched position, the French, under Marshal Massena, captured the fortresses of Ciudad Rodrigo and Almeida, and pressing on Lord Wellington suffered a most severe check and loss at Busaco, where they lost two thousand killed and five or six thousand wounded, while the allied British and Portuguese had only two hundred killed and one thousand wounded. Massena, however, turned the position of Busaco; and as he advanced, Lord Wellington retired leisurely before him, till, filing his divisions, brigades, and battalions in the most perfect order unto their respective positions in the prepared lines of Torres Vedras, the French halted in amazement at the insurmountable obstacles before them.

(At page 124) "Lisbon being situated at the extremity of a peninsula formed by the sea and the Tagus, it is apparent that if an army be so posted as to extend across the neck of the peninsula, no enemy can penetrate to that city without a direct attack on the army so formed. It was on this principle that the lines covering Lisbon were planned by Lord Wellington. Nature drew the rude outline of a strong defensive position, and art rendered it perfect. A tract of country of thirty miles, extending from the mouth of the Zizandra on the ocean, to Alhandra on the Tagus, was modelled into a field of battle: mountains were scarped perpendicularly, rivers dammed, and inundations formed; all roads favourable to the enemy were destroyed; and others made to facilitate the communications of the defenders: formidable works were erected to strengthen and support the weak points; whilst numerous cannon, planted on inaccessible posts, commanded the different approaches to them, and gave an equality of defence to the whole position."

Before these lines the French remained five months, wasting their numbers and resources; and finding all endeavours to force the works to be in vain, they retired out of Portugal, closely followed and harassed by Lord Wellington.

These lines were not continued and connected works; but were formed of independent forts, redoubts, flêches, batteries, &c. placed in the situations most suited to command and enfilade every approach, and to support each other by a cross or flanking fire: the first line occupied a front of twenty-nine miles, between the sea and the Tagus; and by means of telegraphs, information could be conveyed from one extremity to the other in a few minutes; while the troops were disposed in masses in rear of the works, ready to act at any point, by shorter roads than the enemy could take. In all, there were fifty miles of front to occupy; one hundred and fifty forts, and six hundred pieces of artillery, to man and to work.

Colonel Napier, in the third vol. of his Peninsular War, says, "the aim and scope of all the works was to bar those passes and to strengthen the favourable fighting positions between them, without impeding the movements of an army. These objects were attained; and it is certain that the loss of the first line would not have been injurious, save in reputation, because the retreat was secure upon the second and stronger line, and the guns of the first were all of inferior calibre, mounted on common truck carriages, and consequently immoveable and useless to an enemy."

Yet, although the lines of Torres Vedras were thus perfect, and foiled the ablest leaders and the most veteran troops of Napoleon, it is not meant to refer to these separate field works as a model to be copied on all occasions: for while the old school mode of covering a great front by a continued line of regular bastions and curtains, has been universally condemned by modern engineers, there are situations in which a partial application of continued lines may be most judicious.

It is no fixed rule, but the nature of the ground and of the position to be defended that should determine the species of work best calculated to be useful.

307. The foregoing observations serve to show the value attached to this branch of the art by the most celebrated modern military judges, and are more than sufficient to silence the cavils of such writers as endeavour to undervalue the use of these aids.

Voltaire remarks, on the successful assault made by Charles XII. on the Danish retrenched camp before Copenhagen, that, "Troops attacked in their retrenchments are usually beaten, because those who attack have always an impetuosity that those who defend themselves cannot have; and waiting for their enemies in lines, is a confession of weakness, and of an enemy's superiority." There is some truth in this assertion as is shown by the records of successful assaults on positions strengthened by field works; but it is not the whole truth; for military history also fully attests the value and importance of such works, in saving armies from defeat and enabling them to take the offensive. The same author records that it was by an unsuccessful attack on the retrenched Russian position at Pultawa, in July 1709, that the Swedish monarch was ruined, and lost the fruits of nine years' victory and of one hundred combats. Napoleon says that "Even in offensive warfare in the open field, the great secret consists in defensive combats, and in obliging the enemy to attack": an opinion greatly at variance with Voltaire's; the wisdom of which has however been practically shown by our great leader the Duke of Wellington, as must be fresh in the remembrance of all military men; for example at Talavera, Waterloo, &c.

308. Even a limited practical knowledge of war opens a wide field for the exercise of an engineer's talent and resources in field fortification: but the possession of a military coup-d'œil is necessary to know how to turn the theoretical stores of infor-

mation to the best practical uses: it requires an eye experienced in sketching and modelling ground: and, in passing over a country, to seize quickly upon all that it offers, of advantages or disadvantages, to an army destined either to attack or defend it: to know the value of villages, stone enclosures, broken ground; to know where to dam up rivers; to scarp heights; to form abattis; trous-de-loup, and other obstacles; to select the best situations for field forts, redoubts and emplacements for batteries: and to arrange all these defensive means with reference to the number and species of troops that have to act upon the different parts of the line: at the same time, the manœuvres of the defenders must not be cramped or impeded; the communications between the different parts of a defensive line must be short and easy, so as rapidly to convey succour to a part vigorously attacked; and provision should be made to permit the offensive to be easily taken whenever an opportunity offers.

The infinite variety of ground upon which military operations are conducted, precludes the possibility of laying down any very fixed rules on this subject: the ground and circumstances must determine the extent and description of the works and obstacles to be applied in each case.

309. It is now proposed to follow the mode of instruction usually pursued at military schools, and to make such remarks on the various details of field works as some of the features of the late wars, or the published opinions of our best military engineers, may authorize.

310. *Profiles to field works.*—The principles that regulate the height and thickness of parapets, (as detailed in definition 24) must of course hold good in the construction of the like masses for field works exposed to a fire of heavy artillery.

Ramparts are rarely made in field works, as in general there is not time, nor does it become necessary, to construct any thing beyond the covering mass of parapet.

But as field works have seldom to stand the fire of battering guns, their parapets need not be of the same dimensions as those used in permanent works: a less thickness will suffice to resist the fire of light artillery and musketry, and their dimensions therefore depend, in some measure, upon the arms likely to be brought against them.

The object of the ditch being to create an obstacle to an enemy's approach, and to obtain earth from it to construct the parapet or breast work, its capacity chiefly depends on the demand for the latter. The obstacle can be increased by deepening and widening its dimensions, but to do so beyond its due limits, gives more earth than is required; to excavate and remove which, takes time and labour, besides the difficulty of flanking ditches of a capacity beyond due proportions (Paragraphs 28, 128, &c.).

The height of a parapet, however, in field works scarcely differs from that in permanent works, as it must always be high enough to give good cover to the defenders in its rear; and when the contending parties are on nearly the same level, nothing less than seven feet can be considered as sufficient for this purpose: this is illustrated in fig. 142, which represents the section of two faces *h*, *i* of a square redoubt, and the elevation of another face, *ef* connecting them together, the crests of the parapets being four feet and a half above the ground line. A man without the work would, in the act of firing, have his musket at his shoulder, or at four and a half feet from the ground, as at *A*, and a horizontal shot from him would sweep evenly along the line *fe*: while a man firing from behind a parapet, *B*, would plunge his fire *B D* into the interior of the work.

In fig. 143, where the crest of the parapet is six feet above the level of the ground, the cover is better, but still not sufficient to neutralize the effects of an enemy firing over a parapet seven and a half feet high from without. In fig. 144 this is completely obviated by the parapet being made seven feet and a half high.

Still, if a work be intended merely to hold out against a sudden assault, without the process of a regular attack against it, six feet height of parapet will, in many cases, be sufficient.

The dimensions laid down in fig. 145, are only suited to cover an ordinary guard, and not for resistance: fig. 146 is for a like purpose but will hold together for a longer time: figs. 147, and 148, may be used as cover to resist an attack of musketry: fig. 149, is suited for redoubts, bridge heads, retrenched camps, and lines, raised to resist sudden attacks of musketry and very light field artillery.

Fig. 150 is equal to resist an ordinary attack made with nine pounders: fig. 151 is a much stronger profile, and, when time will admit of its construction, it may be applied to withstand an attack from light artillery. Fig. 152 will resist twelve pounders; and fig. 153, is adequate to meet an attack from eighteen pounders, and of making an obstinate resistance.

The medium dimensions of the above figures, however, are those most commonly in use: the first figures, 145 to 148, being too slight to offer a sufficient obstacle, and the latter figures, 152 and 153, too massive to construct with the limited time usually at command for such works.

In each of these figures, except 149, the scarp or reverse slope of the ditch is represented as one continued line from the foot of the superior slope of the parapet to the bottom of the ditch, and this construction is assuredly more difficult for an enemy to overcome, than a parapet with a berm, as in fig. 149: but this berm is of great use in the construction, as it gives a step or footing for the workmen; and should the work have to stand for any time, or should the soil be loose, the berm gives it greater stability; its advantages therefore are such as to induce engineers in many cases, to prefer it to the continued exterior slope.

The front or counterscarp slope of the ditch should always be made at as steep a slope as the earth will stand at; to render it difficult for an enemy to descend; and, as it is always desirable to increase this obstacle, it can be done by making a small glacis, as in fig. 149, which has besides the advantage of covering the parapet in part from the enemy's view: the height of this glacis should never be such as to interfere with the guns in embrasure which must always range freely over it.*

311. These profiles, however, need not be adhered to; the soil, in some cases, requires great slopes to be given to the parapets and sides of the ditches. In the lines of Torres Vedras, the profiles had generally a berm of two feet, and the sides of the ditches sometimes met at an angle at the bottom, as fig. 154; this was a most judicious construction, as the redoubts in these lines were rarely flanked, and thus any thing like a settled formation of troops in the ditch was prevented; the defenders, on this occasion, were abundantly supplied with that most useful weapon, hand-grenades, to shower over the parapet into the ditch, to supply the want of a flanking defence.

Figs. 155 to 160, are examples of profiles under the various circumstances therein represented; and are given as hints, which it is hoped may prove useful. The dotted line *a b* in each of the profiles showing the original outline of the ground.

312. In excavating and constructing a redoubt, &c., it is of great importance to secure its being well drained in the interior, especially if the terre-pleine be sunk below the level of the ground, else it becomes a mere pool of water in continued rain.

In tracing field works, the slopes of the ground must be well considered, and all the arrangements for draining them prepared before the work is commenced upon, as by laying the drains in good time, much labour may be saved afterwards.

313. *Trace* proper to be given to field works. This must depend upon the situation and importance of the works; the number and species of the troops, and the quantity of artillery

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* These observations are illustrated by the construction of the field bastion in the grounds of the seminary; the scarp is one continued slope, and soon required repairs; the small glacis increases the height of the counterscarp, and covers part of the parapet; its crest being on a line with the slope of the soles of the embrasures.

intended to occupy and defend them. It is usual to divide them into three classes.

First, Works open at the gorge,
Second, Works enclosed all round,
Third, Lines; connected, or at intervals.

Redans, or simple heads	are the names given to the various tracings of the first class, or open works.
Double redans, or queues d'hyrondes	
Tenailled heads . . .	
Bastioned heads . . .	

Redoubts	are the names given to works under the second class, or closed works.
Star-forts	
Bastioned forts . . .	

Lines à crémaillères . .	are the names given to the works of the third class, or lines.
Lines of redans . . .	
Lines of tenailles . .	
Lines of bastions . . .	
Lines at intervals . .	

314. Some of the received maxims of permanent fortification are equally necessary to be observed in the construction of field works.

1st. That the works to be flanked are never to be beyond the range of the missiles of the works flanking them; that is, never out of the effective range of musketry, or from one hundred and fifty to two hundred yards.

2d. That the angles of defence should be about right angles.

3d. That the salient angles of works should be as obtuse as circumstances will permit.

4th. That, although ditches cannot always be as fully flanked as in permanent fortification, yet that partial flanking must be carried as far as possible.

5th. That in the construction of field works, reference should not only be had to the direct and immediate obstacles that the work itself presents to the enemy, and the positive effects of its fire on the approaches to it; but likewise the relative value of the work must be considered, as to the support it can give to, or receive from, other works.

315. *Redans* (fig. 161) are the simplest kind of trace for field works; having two faces forming a salient angle: they serve to cover bridge heads, causeways, avenues, &c.: and being quite open at the gorge, are only suited for defence when resting their extremities on rivers, or obstacles which prevent their being turned; or else, when within the full sweeping fire of works in their rear; that an enemy may be deterred from any attempt to assault by the gorge. Redans in front of other works are generally mere cover, for an advanced post; for example, if a strong redoubt occupies the commanding summit of a hill, its elevation and position usually prevent the deep hollows and approaches by the vallies being fully seen from its faces; redans or flèches may then be advantageously constructed on the lower knolls, or under features of the hill, to see into all the hollows, while the fire of the main redoubt plunges into their interior.

To increase the strength of a large redan, its faces can be broken into flanks, as in fig. 163: this brings a portion of flanking fire upon the ground before the salient angle of the work: and if the parapet be formed as at *a*, fig. 161, 162, perpendicular to the capital, the fire from it, will bear directly upon the ground before the flanked angle.

Redans have the defect of unflanked ditches; their profile should therefore be like that represented in fig. 154, and the defenders should be provided with hand grenades to throw over the parapet for the defence of the ditches.

To obtain a defence for the ditches of redans situated in front of other works, their extremities should be directed upon some of the faces in the rear, and sloped up, *à la rampe*, (as in fig. 174, *cd*), to receive a flanking defence.

Redans having flanks are sometimes called *lunettes;* the position and extent of these flanks depend upon the purpose for which they are given, and the ground that they have to flank (as fig. 162).

Two redans joined together, as in fig. 164, form the double redan; a shape and size that may, in some cases, be more convenient than the single redan; besides which, the re-entering faces mutually defend or flank each other: this double redan gets the name of *tête queue d'hyronde.* The re-entering angle at *d*, should be as near a right angle as possible; the front *b b*, about sixty yards; the angles at *b*, never less than 60°: and the flanks *b d*, about thirty yards. Should the ground to be defended require more extended works of this trace, those shown in figs. 165 and 166 may perhaps suit.

Tenailled heads are traced as in figs. 167 and 168, the fronts *b b*, being from sixty to eighty yards in length; but if the ground admits of, or requires, a greater extent of front, a *bastioned head* (as fig. 169) may be constructed, of dimensions suitable to the ground.

316. *Redoubts* are works enclosed on all sides, of a square, polygonal or circular figure: the latter form is rarely used, from the unsuitable nature of such an outline to ground in general; from the difficulty of the construction; and the total impossibility of giving any flanking defence to its ditch.

Redoubts are commonly square figures in their trace, as each front can then furnish a steady strong fire perpendicular to its face, see fig. 170; and provision should be made to defend the ground before the angles.

Whether the outline be square or pentagonal, every endeavour should be made, in tracing a redoubt, to direct faces upon the ground either inaccessible or difficult for an enemy to possess; not only to guard against his enfilade fire, but, if possible, to hinder him from approaching upon the angles, and compel him to advance upon the faces, from which comes the strongest fire.

There are several ways of remedying the want of fire upon the spaces before the angles: see fig. 171. The first is by cutting off the vertex of the angle by a straight line, as *a*, so as to obtain a fire of musketry from as many files as the banquette will hold; second, by rounding it for the same purpose as *b*; third, by forming an embrasure or barbette on the capital, as *c*; fourth, constructing the parapet en cremaillère, as *d*; that is disposing the parapet in a succession of small salient and re-entering angles, alternately parallel and perpendicular to the capital, in order to obtain a musketry fire upon the ground before the angle: all these modes are good when properly and judiciously applied.

Still, in square redoubts, as figs. 170 and 171, the ditches remain unflanked, and unless the contrivances described in paragraph 324 be resorted to, it is advisable to form them of the profile of fig. 154, and to furnish their defenders with an ample supply of hand grenades.

317. *Star forts*, represented in fig. 172, were proposed to remedy the defect of redoubts that have the ground before their angles undefended by a flanking fire: by this arrangement a cross fire is brought upon the ground before the angles: but in consequence of the great exterior slopes necessarily given to field profiles, the lengths of these faces are greatly diminished, affording but a feeble quantity of fire from each; and for the ditches, the flanking defence, amounts to almost nothing. Baron Jomini says, that "star forts are the very worst description of fortification; they cannot have flanks, and the re-entering angles take so much from the interior space, that it is impossible to place troops and artillery in them sufficient for their defence: they are especially exposed to be enfiladed from one end to the other, which precludes the possibility of their making a long defence." An opinion confirmed by the practice of Sir Richard Fletcher and Sir John Jones, in the construction of the lines of Torres Vedras: where the trace of the redoubts was

made subservient to the shape of the ground, to the object in view, and to the protecting of them, as much as possible, from the fire from the enemy's position.

318. *Bastioned forts.* Fig. 174 shows the tracing and dimensions of a bastioned fort upon a square; the principles of construction correspond with those detailed in the permanent portion of this treatise, and need not therefore be repeated; the flanking defence thus obtained for the ditch is nearly perfect on the front *a*: but the ditch is sometimes made as seen on the front *b*, where the portion *cd* is formed in a ramp sloping upwards from *c* to *d*, in order to obtain a flanking defence from the adjoining flank: here the flanking defence is not so good as on front *a*, nor is the obstacle of the counterscarp perfect all round, but provides a descent for the enemy into the ditch by the ramp in the case of sudden assault.

As bastioned forts would be constructed only in cases of great importance, where it is wished to present every obstacle to an enemy, and to hinder him from getting possession of the ground upon which they are placed; such works should have every possible labour and means expended on them, to make them as formidable as possible. In small works, it is impossible to obtain good flanking defences for the ditches, from the want of interior capacity; but in great forts, which generally form the key of a position, the interior space lost by breaking the faces into flanks is more than compensated for, by obtaining a good defence for the ditches. The experience gained in the Peninsular war has fully proved that field forts or redoubts, having unflanked ditches, cannot stand against determined and skilful attacks.

All the accessories to be hereafter mentioned, such as fougasses, abattis, trous-de-loup, fraises, palisades, &c., (paragraph 326) should be used to strengthen bastioned forts in the places considered most suitable for them.

Forts, with demi-bastions, as in fig. 173, are objectionable, as the ditches *ee* before the faces of the demi-bastions are only obliquely and imperfectly defended from the long faces *ooo*.

In fig. 174, front *a*, there is a passage of ten or twelve feet wide left in the curtain, leading to a bridge thrown across the ditch, covered by a small re-entering place of arms; and if the counterscarp can be raised three or four feet above the ground line, it would serve to cover the exit considerably: the passage and bridge is defended by a traverse *t*.

The entrance into all field works should be made in the most retired and safe parts, generally at the re-entering angles most distant from the enemy; and as narrow as the nature of the service will permit.

319. *Lines.*—Continued lines or connected works, are sometimes resorted to, in order to enclose the front of a position, or to connect important redoubts or forts together.

Fig. 175, shows the most simple tracing of lines; being redans connected together by curtains of parapets; but as the ditches of these curtains are only defended by an oblique fire from the portions of the faces of the redans that view them, it is proposed to remedy this by breaking the curtains so as to form nearly right angles with the faces of the redans: thus modified, they take the name of lines of tenailles, fig. 176.

Fig. 178, *a a*, shows the tracing and general dimensions of lines en crémaillère; having long faces and flanks perpendicular to them to defend their ditches: and when these long faces can be directed towards inaccessible ground upon which an enemy cannot establish enfilading batteries, the construction is considered good: or as in the case shown in fig. 178; where this tracing is applied to unite two large works together: and where the long branches of the crémaillère are directed upon the salient of the great works, *b*, and therefore cannot be enfiladed by an enemy.

Bastioned lines, as shown in fig. 177, are the strongest trace that can be given to continued lines, when the ground admits of its being done. A perfectly regular trace, as seen in this figure, is only suited for level ground, but it may be applied with modifications to suit unequal ground.

In this construction, the ditches of the faces are prolonged *en rampe* towards the adjoining flanks, that they may receive a flanking fire; for if the ditch were constructed as recommended for the bastioned fort, (fig. 174, front *a*) the deblai would far exceed the remblai of the lines, and occupy much time in its excavation.

320. *Lines with intervals.* Fig. 179 shows the general trace of lines of this kind: the salient works should never be beyond the range of the musketry of the re-entering works; and the angles of defence between the two lines of works should be as near right angles as possible: the ditches of the salient works should be formed *en rampe* to receive a flanking fire from the re-entering line of works.

The tracing and dimensions of the works composing these lines must always depend upon circumstances which are too numerous to be mentioned here; such as the shape of the ground; the means and power of the army thus entrenched, to take the offensive, &c. Should the latter be great, lines at intervals are far preferable to continued lines, as the offensive movements are free in every direction: it was thus that Jourdan in 1794 gained the battle of Fleurus; that the Russians in 1807 made so good a resistance in the strong position of Heilsburgh: the works of the famous retrenched camp of Frederick II. before Schweidnitz (mentioned in paragraph 170) were of this description; as also were the spendid lines of Tores Vedras.

321. In comparing the results of the defensive properties of continued lines, with those of lines at intervals, military history bears testimony to the superiority of the latter.

Sir John Jones observes that to cover an extent of country with continued lines, is a most injudicious and weak proceeding: all parts require equal guarding; for if forced at one point the whole is gained; the number of men also that is required to man so great a development of parapet, as the trace of all kinds of continued lines present, is so great as to cramp the means of making any immediate and formidable offensive movement: and thus both defensive and offensive operations are marred by an army having its entire front covered by continued lines.

Sir John Jones, however, with his characteristic talent and judgment, remarks that "field defences are not to be indiscriminately condemned or rejected because they are continuous or systematic. In order to strengthen the front of an army with judgment, it is necessary to consider every feature and every portion of the ground separately, and arrange such mode of occupation as shall best combine its particular defence with the general defence of the position. Thus, in parts unfavourable for manœuvring, it may be advisable to form a continued line of considerable extent, covered with every nature of obstacle, and having none but the most confined outlets, on the principle that a range of difficult heights would be scarped, or low ground inundated, to lessen the number of men on those points, and have a superabundance of force for other points favourable for offensive movements. Again, since the employment of artillery in masses has been introduced, and that an irresistible fire, sometimes of hours' duration, now invariably precedes the advance of the columns of attack, it will frequently prove a good measure, in situations where natural cover cannot be found from a cannonade, to create it artificially between all the prominent defensive posts.* Thus each furlong of ground being duly considered, and the nature of defence best adapted to the locality being formed, the whole front of an army may occasionally be covered with lines of works, which, while they augment its defensive powers, leave its movements perfectly free."

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* This might be effected by means of a sunken trench, like a parallel at a siege, (as *c d*, fig. 178), made to connect a whole chain of redoubts. Such an expedient would cover infantry from the fire of guns without impeding their forward movement in line, and openings might be left for the advance of the cavalry and artillery, or they might act in masses on the flanks.

322. *Bridge heads* are field works generally open at the gorge, resting their flanks upon the banks of a river, in order to cover one or more bridges.

The magnitude and figure of these works depend upon the importance attached to the bridges; whether they are intended to serve as a temporary or a permanent passage during the campaign: whether the army, in retreating, is likely to be exposed to a serious attack in passing the river, &c.

The most favourable situation for a bridge head is in the re-entering sinuosity of a river, as in fig. 183: because the work can then, in some cases, conceal the bridge from the enemy's view and make it difficult for him to enfilade it: as also that in such a position, the supporting batteries on the opposite side of the river, are most favourably situated for aiding the defence and passage of the river.

As têtes-de-pont or bridge heads, are usually constructed for the specific object of aiding a retiring army to pass the river in order, and to check an enemy pressing upon it; the tracing and profile of the works must be such as to secure this double advantage as much as possible.

In the trace, a sufficient number of good openings, *a a*, fig. 183, should be left in the re-entering angles to permit the retiring divisions, with their guns, carriages, &c., to file through with ease; but disposed, as seen in this figure, to flank and defend these passages in every direction.

The various figures shown from figs. 161 to 169, may be used as bridge heads according to the importance of the passage: fig. 180 is a simple redan to cover a passage of small importance across a narrow river, supported by a musketry fire from the parapets *ff* on the opposite side. In fig. 181, the river *X* is wider; the bridge of more importance, covered by a horn work, and supported by batteries of artillery *e e*; as also a battery *f* to enfilade the bridge. Their profile should always be strong, as the pursuing party will not fail to employ masses of artillery to destroy their parapets and uncover the bridge: an interior range of parapets, or a redoubt, as *bb* fig. 183; and *o* fig. 181; would therefore be proper to secure the bridge as long as possible: fig. 182, shows the disposition of works to cover bridges, where there is an island in the river, and a village on the side of an enemy.

Great têtes-de-pont, are works constructed to defend the bridges which cross a river covering part of the frontiers of a state, in order to preserve the communications by which armies may advance into, or retreat from, an enemy's country.

" In the campaign of 1645, Turenne was attacked with his army before Philipsburg, by a very superior force. There was no bridge here over the Rhine, but he took advantage of the ground between the river and the place to establish his camp. This should serve as a lesson for engineer officers, not merely in the construction of fortresses, but of têtes-de-pont. A space should always be left between the fortress and the river where an army may form and rally without being obliged to throw itself into the place, and thereby compromise its security. An army retiring upon Mayence before a pursuing enemy, is necessarily compromised; for this reason, because it requires more than a day to pass the bridge, and because the lines of Cassel are too confined to admit an army to remain there without being blocked up. Two hundred toises should have been left between that place and the Rhine. It is essential, that all têtes-de-pont before great rivers should be constructed upon this principle, otherwise they will prove a very inefficient assistance to protect the passage of a retreating army. Têtes-de-pont, as laid down in our schools, are of use only for small rivers, the passage of which is comparatively short."

" Marshal Saxe, in the campaign of 1741, having passed the Moldau in quest of a detached corps of fourteen thousand men, which was about to throw itself into Prague, left a thousand infantry upon that river, with orders to entrench themselves upon a height directly opposite the tête-de-pont. By this precaution, the marshal secured his retreat, and also the facility of re-passing the bridge without disorder, by rallying his division between the entrenched height and the tête-de-pont."*

The pupil is referred to "An essay on the principles and construction of military bridges and the passage of rivers in military operations; by Major General Sir Howard Douglas, Bart. C.B." for full, scientific, and most interesting information on this important subject.

323. The periphery of a work, and the number of men to defend it, should bear a just proportion to each other; for this purpose three running feet of parapet is required for each man to use his arms freely, so that the number of yards and the number of men for each face, agree; and no difficulty occurs; for no deduction need be made for the space occupied by artillery, as the spare men arising therefrom, will form a reserve to fill up casualties or to meet a sudden assault at any point.

It has been customary in calculating the area of enclosed field works, to allow ten square feet for each man, and three hundred and twenty-four square feet for each gun and its stores; an estimate that need be attended to, only in the case of the garrisons of the redoubts being always confined within the parapets: this is rarely necessary, for during the day their drill, amusement, and cooking, will be without; and, in case of attack, in a system of works, the general formations of the troops will also be without, while the redoubts have only their parapets lined.†

324. From what has already been stated of the usual trace of field works, it is evident that their ditches are rarely defended by a flanking fire; some contrivances have been proposed to remedy this defect.

One, is the construction of a gallery behind the counterscarp as *g*, fig. 171, and *g*, fig. 152, having loop-holes looking into the ditch to defend it by a reverse fire of musketry: in chalky soil, where galleries can be easily formed, this species of defence is most suitable, as the reverse gallery can be connected to the interior of the work by a gallery of communication, as *h*, figs. 152 and 171: this was the case in one of the redoubts on the lines of Torres Vedras: but where the soil does not favour this construction, the reverse gallery can be made without any such communication; as was done by the French in the defence of the lunette Picurina, (*P*, fig. 29).

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* From the Military Maxims of Napoleon.

† Sir John Jones's Lines of Torres Vedras

Another mode of flanking a ditch is by means of a covered caponniere, as in figs. 184, 185, and 186; formed by a double row of strong palisades at seven feet from each other: these palisades are united to each other like a stockade, and have loop-holes at three feet asunder: this passage is covered with strong beams, with layers of fascines, dung, and fresh hides, to preserve it from destruction; this covered caponniere is connected to the interior of the work by a gallery of communication *r*, fig. 185; supported in the usual manner by stanchions and sheeting: this is laid in the original construction of the work.

Lastly: when a work cannot be turned by the gorge, a simple caponniere of close palisades, as *cc*, fig. 106, will furnish cover for a party to flank the ditch.

325. The form and dimensions of the work being determined, and a correct plan of it made on paper, it is traced on the ground by fixing a strong picket at the chief salient angle; and, by means of instruments for taking angles and measurements, the salient and re-entering angles of the various faces are fixed, and staves driven in at these points: this course of pickets represents the crest of the parapet: lines parallel to this are traced, scored, and picketed, at the angles, to show the breadths of all parts of the banquette, parapet, and ditch, and lath profiles being prepared, are set up on the various faces perpendicularly to the length of the parapets.

When the work is intended to receive artillery, the directions laid down in paragraphs 269 and 270, must be attended to, while the work is going on; as also what is there said of the manner of excavating and revêting.

The nature of revêtements for field works has already been described from paragraphs 73 to 80, and from paragraphs 252 to 261.

326. The obstacles usually added to render the approaches to field works, and the possession of them, more difficult to the enemy, are as follows:—palisades, barriers, abattis, trous-de-loup, chevaux-de-frize, harrows, and crows-feet; the first four of these obstacles should be formed with great attention, as it greatly daunts the ardour of the best assailing troops to be checked, and to have their formation broken, under a near fire of musketry, without the power of immediately closing with their opponents.

Palisades.—Sir John Jones, in the first vol. of his Sieges, page 471, says, "The French plant admirable palisades in the ditches and rear of their works: each palisade is the rough stem of a young tree, or the half of a larger tree, fixed to a heavy beam four or five feet under ground. To cut through these palisades, in their usually confined situations, is the work of half an hour, and to force them out is impossible, so firmly are they planted. They are, therefore, an excellent defence when covered from cannon, and might be adopted by the English in many situations with great advantage to the service."

Palisades are fixed in ditches in the various ways shown in fig. 149, *a b c d:* those inclined as *a* and *d* are called *fraises;* the construction *a*, on the scarp, is not much approved of; a good range of these, served, in one instance, during the Peninsular war, to place the scaling ladders against, and to give the assailants a tolerable footing before rushing over the parapet. In a very steep scarp slope, a range of palisades at its foot, as at *b*, forms a kind of revêtement, which may be made very formidable when the wood is of a large rough scantling: that at c, is also useful, and difficult to cut down, should the assailants attempt to descend the counterscarp; *d*, is likewise a difficult disposition of fraising when well inclined downwards, for to cut it away requires time, while the assailants are exposed, in doing so, to the full fire of the parapet.

When it is suspected that the ditches have obstacles, the attacking party will scarcely neglect to bring an enfilading fire into them, both from cannon and howitzers, when the palisades cannot fail to receive much injury: the arrangement, c and d are then most likely to suffer least.

Barrier gates, to close in the entrances of field works, should be very massive, and capable of resisting any sudden attack; they may be made of strong palisading; swept by the fire of a traverse; and are always on the least accessible side.

Abbattis are lines of felled trees of a considerable size; their stems strongly bound together and picketted down, while their branches are spread towards the enemy, and interlaced as much as possible: the small branches are cut away and the boughs well pointed.

Figs. 151 and 153 show the situation in which abattis are recommended to be placed: that in fig. 151 covered by an advanced glacis, which hides the abattis from the view, and the fire of the enemy's artillery, is much approved of.

At page 360 of the third vol. of Colonel Napier's History of the War in the Peninsula, in describing the lines of Torres Vedras, it is said, "across a ravine on the left a loose stone wall, sixteen feet thick and forty feet high, was raised: and across the valley of Aruda a double line of abattis was drawn, not composed, as is usual, of the limbs of trees, but of full grown oaks and chesnuts, dug up with all their roots and branches, dragged by main force for several hundred yards, and then reset and crossed, so that no human strength could break through. Breast-works, at convenient distances, to defend this line of trees were cast up, &c."

Well disposed abattis make a formidable obstacle, and have always been highly esteemed and much used in ancient and modern warfare.

Trous-de-loup are rows of pits in the form of inverted cones, made before a work, and having a strong palisade or stake in the centre of each, as c, fig. 153: these used to be about six feet deep, and eight or ten feet diameter at top; but upon some occasions, during the Peninsular war, bold and active riflemen crept into them, and brought a most destructive fire from these close covered situations upon the gunners of the defenders; to prevent which, it is recommended to make their depth only two or three feet, to increase the number of rows, laying them out chequer-wise; the earth removed from these trous used to be spread around the mouths of the pits to increase the height of the sides; but, as it has just been shown that this is not desirable, Sir John Jones recommends an advanced glacis to be formed with the soil, to conceal and protect the rows of trous-de-loup from cannonade.

Chevaux-de-frize are formed by inserting iron pointed stakes of five or six feet long into a heavy beam of wood; if the beam be square, the chevaux-de-frize will have four projecting spears, as *f*, fig. 151; if hexagonal, it will have six spears: these beams are from six to nine feet in length, and are chained together in a line to cover the ground required.

Chevaux-de-frize are troublesome and require much time to construct, and are greatly inferior to abattis for the defence of field works.

Harrows, such as are in common use on farms, are recommended to be spread upon the ground over which an enemy is likely to pass in the attack.

Crows-feet are pieces of iron with four points, each, four or five inches long, projecting in different directions, intended to be used to impede the approach of cavalry: neither these or harrows have been in use of late.

827. *Instructions for the defence of open towns and villages.*[*] In defensive warfare, it is often necessary to intrench towns and

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[*] Issued by the French imperial minister at war in 1814, and translated from the French by Brevet Major Reid, Royal Engineers, for the establishment for field instruction, royal engineer department, Chatham.—1823.

villages, either for the purpose of securing them from the incursions of small parties, or to serve as points of support for the movements of troops.

"The following are the most simple methods of rendering them defensible, and those which are most in use.

"To admit of a town being advantageously intrenched, it is in general necessary that it should not be commanded within a very short distance, that the houses should not be of a construction to be easily set on fire, and that its extent be not out of proportion to the means and time at the disposal of the defenders.

"The first thing to be done is to clear the approaches to the town, by levelling houses, hedges, shrubberies, and whatever may not be of advantage to the defence or whatever may favour the assailants. Wood ought to be cut two feet from the ground that it may serve to impede the advance of the enemy, without masking the fire of the defenders.

"The next object is to form or complete the enclosure round the town. For this purpose, advantage is taken of buildings, walls, and fences, applicable to the defence. The openings which remain must be closed by means of palisades, stockades, or ditches, strengthened by abattis; figs. 187 and 188 are intended to give an idea of the general dispositions for this purpose. Figs. 189 and 190 show more in detail the systems followed in forming these defences. All streets leading directly out of the town must be barricaded: these barricades ought to be sufficiently thick to resist field artillery, and high enough not to be easily got over: they ought to be flanked by loop-holing the neighbouring houses, as is shown in fig. 191.

"They may be constructed with palisades, or in stockade work: or else a frame may first be made with uprights and planks, and then it may be filled in with earth or dung: as in figs. 192 and 193.

"When pressed for time, such barricades may be formed by filling carts or waggons with earth or dung: the wheels are taken off: and if trees be at hand, an abattis may be formed in their front; as in fig. 194.

"Sand-bags, and also bales of wool or cotton, may be used as in fig. 195.

"If there be any drains or galleries under the town, they must be stopped by gratings or otherwise.

"The openings necessarily left for the purpose of sallies are covered by tambours of palisades, or by abattis; and such openings should be closed by a barrier, chevaux-de-frize, &c. One complete line of defence being finished all round, that which will most tend to strengthen it, is next to be considered.

"Advantage must be taken of the most salient points to establish flanking defences, whether by loop-holing the houses, constructing tambours, or any other field works.

"If there be artillery, it ought to be disposed so that it will fire upon the enemy in his advance, and protect those parts of the defences which are most liable to assault. It will generally be placed behind salient points of the line of defence, whether consisting of earthern works, tambours, or of old walls. In the latter, embrasures must of course be opened.*

"It is proper to cut a ditch in front of the parts where the defence consists of buildings or enclosures; and if there be time or means, it is desirable to continue this all round, and to encrease the obstacles by palisades and abattis.

"If a town be situated near a river or stream, by which any part of it can be covered by inundations, it should never be neglected: this valuable defence is shown in figs. 187 and 196.

"When the quantity of water to be retained is inconsiderable, the dams may be made with fascines and stakes, as in fig. 197.

"Fig. 178 represents a dam formed on the upper side of a bridge, by means of beams and fascines.

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* Flat roofed buildings are sometimes found strong enough to bear light artillery, whence a commanding view of the country may be had; ruined houses with strong walls have been filled up with earth and rubbish, so as to form a solid cavalier battery.

"If there should be any old castle, church, or large substantial building inside of the town, it may be converted into a keep, by blocking up useless openings; by covering entrances or any unflanked portion of the wall with a tambour; by loop-holing the walls, and by surrounding them, if possible, by a ditch, with palisades and abattis.

"Care should be taken to barricade all streets not required for the movements of the troops, or those by which the enemy might cut off the retreat of the garrison to this keep.

"In cases where the strength of the garrison will admit of an obstinate or protracted defence, due advantage must be taken of all buildings, situated within the line, that may be adapted to the purpose, by intrenching them, and connecting them with each other, or with the town, by means of field works, ditches, or abattis.

"*Villages* are to be intrenched on principles similar to those just proposed for towns. It is necessary to remark that villages being generally surrounded by gardens enclosed by live hedges, these hedges may be made use of in forming the line of defence. A small ditch may be dug in front of them, or else an abattis must be placed there as an obstacle: fig. 196 is an example of a village intrenched in this manner; and fig. 199 represents, on a larger scale, the detached works covered and connected by abattis.

"That the communications in the interior may be free, all hedges and enclosures, which may in any way impede the movements of the defenders, must be levelled.

"If there should only be troops sufficient to defend part of the village, then a part only must be intrenched, which must be separated from the rest of it by cuts and barricades.

"If there be very few troops, it may be necessary to confine the defence to the church or churchyard, which in all cases may serve as a keep."

328. *On the attack of field works.* If the works to be attacked are of a slight description, having few obstacles and an insufficient garrison to occupy their whole developement, the

bold and rapid attack of superior numbers, without the aid of artillery, will probably be successful: the assaulting columns attacking at several points at the same time, and always threatening the communications of the defenders. But it rarely happens that the musket and bayonet suffice without the aid of artillery, which is necessary in order to silence the defensive batteries, and to make openings in the obstacles and lines, for the columns of assault to attack in regular order.

Usually, the artillery of the assailants take up their position within good range of the works; some batteries opposite to, and some upon the prolongation of, the several faces, in order to silence the defensive artillery, to ricochet the faces, break their palisades and fraises, and enfilade their ditches: as howitzers now always form a part of field batteries, their fire is a most useful auxiliary in the attack of field works; the quantity and calibre of the artillery to be employed, as well as the cover necessary to construct for the batteries and the troops, must depend upon the importance of the works attacked; the principles of the attack of permanent works being followed in cases of well covered and extensive works.

If there be any commanding ground on which the assailants can establish batteries, and plunge their fire into the works, it must be seized; and the light troops will lodge themselves in all the cover within range of the works; and, if necessary, epaulements will be formed to give them cover.

When the fire of the artillery of the assailant has subdued the fire of the defenders; cut openings through their abattis, stockades, and barriers; and, if possible, enfiladed their barricades and interior defences; powerful columns of assault will attack by these various avenues; the columns are always accompanied by sappers or artillerymen, armed with axes, crowbars, &c. to force barriers: bags of hay, fascines, sand bags, &c. to fill up chasms, and throw into the ditches; while companies of riflemen deploy along the whole outer developement, to keep down the enemy's fire.

Previous to the signal of attack being given, the batteries keep up a powerful fire, which is continued even during the advance of the columns as long as it is safe to do so; the columns, in their march, advance as much as possible on the capitals, or the parts having no direct fire: if the works be isolated, some of the columns of attack will seek to turn them by the rear, and gain possession of the roads by which the defenders must retire.

Some pieces of artillery should follow the columns of attack in order to assist in destroying interior barricades, &c.; to force which by the bayonet, is always a destructive, and generally a fruitless, operation, especially when the neighbouring houses are possessed and loop-holed by the defenders; and when there is no means of turning the barricade.

To force a barricade in a street, it is recommended to throw up rough cover for the gunners, and to bring up a piece of artillery to play upon it, while the infantry break into the houses on each side, and force through the party walls of the houses, getting possession of each in succession, and thus turning the barricade: a few loaded muskets applied to the locks and bolts of the strongest door will force it open: when the superior numbers and means of the assailants should prevail in getting possession of the houses.

In the attack of lines at intervals or unconnected redoubts, it would probably accelerate their fall, to make vertical fire from howitzers, and if possible from mortars, enter greatly into the means of attack, since it cannot be supposed that there is any thing beyond the slightest splinter proof cover, if there be even that, in such works; and their small interior capacity would be very favourable to the destructive effects of vertical fire.

In the attack of all field works, howitzer shells, and spherical case, will be most effective aids to direct fire; indeed, in some cases, vertical fire should form the very basis of the attack.

CHAPTER XII.

Of fortification upon irregular ground.

Of defilement.

329. Two causes produce an alteration in those regular forms of fortification that have hitherto been detailed.

1st. The irregularity of the ground upon which the works are constructed.

2d. The influence of heights within the range of artillery.

330. With respect to the first; the infinite variety of sites upon which it may become necessary to construct fortresses, renders it quite impossible to fix such precise principles as have already been laid down in speaking of the construction of a fortress on a horizontal site.

Nevertheless, some general principles have been recommended: such as occupying the crests of hills with important works, having the revêtements covered by a glacis; yet so arranged amongst themselves that the face of the hills and all the approaches, may be seen and flanked; to do which, advanced redoubts, lunettes, and flèches, generally become necessary on the under features of the hills, from which the faces and slopes of the hills can always be better seen than from the highest parts.

The salients (which ought to be few in number) should, if possible, be upon ground before which an enemy will have difficulty in constructing his trenches, either from the soil being marshy, rocky, sandy, or difficult to work in.

If necessary, one bastion may be made larger than another; a curtain may be broken into faces; ravelins may be suppressed, enlarged, or diminished; a flank may be lengthened or shortened; fronts may have their ordinary dimensions increased or lessened;

and when the rise of the height is very rapid, it utterly precludes the formation and use of batteries à ricochet; besides which, their glacis, terminating in a very sharp angle at its crest, occasions an enormous labour to the besiegers to form a sufficient base on which to place their breaching batteries. Such are the glacis of St. Salvador at Corfu; and of Fort La Lippe at Elvas.

"It should, however, be mentioned, as some counterbalance to these advantages, that a height of one continuous and rapid ascent gives a facility to a besieger for pushing forward his approaches, because, on an inclined plane, less height of parapet gives cover in the sap, than when formed on a horizontal base: and the guns of works on the steep heights can seldom be depressed to fire directly on the trenches; and the progress of the sap can only be opposed by musketry, or vertical discharges.

"To carry approaches from a height against a work situated on a parallel height, having a valley between them, is attended with considerable difficulties; for, if the side of the hill to be descended be very steep, no practicable depth of trench or height of parapet will give cover to the troops, unless each return of the approaches be directed very much clear of the salients of the works under attack, which increases considerably the length of each return, and consequently the labour of forming it; and even after this additional labour, the ordnance next the salients of the besieged place, which take the approaches en écharpe, have a murderous effect.

"It is apparent that as the approaches nearly reach the bottom of the valley these evils increase, and that all the advantages of defence to be drawn from height of situation, operate against the besiegers' trenches in a ratio according to the steepness of the descent, and the relative height of the sides of the valley; therefore any plan of operations, which necessitates carrying the approaches across a valley for the attack of a work on the opposite side, should, if possible, be avoided": for example, in fig. 202, plate 13, instead of descending the hill on the line, *Q R O*, directly in face of the fire of the place, it would be preferable to issue from a ravine, as seen by the trenches, *a*, *b*, *c*, *d*, *e*, *f*, where the prolongations of the trenches fall without the works attacked; and being also upon level ground, they are not subject to the labour and inconvenient construction just pointed out.

"From these various counterbalancing properties, resulting from height of situation, it may be concluded that a fortress is not to be pronounced of great strength from the circumstance of elevated situation alone; for, even to form a moderately just opinion of its strength, it must be ascertained that its walls are all covered from distant batteries, that its interior be casemated, that the face of the height be under fire of the ramparts, or if precipitous, that it be flanked on every point. If such, however, be found to be the case, height of situation must be considered to add greatly to the defensive powers of a place, and demands our respect."

The foregoing able remarks, on the true value of commanding ground, show how carefully the defensive works should be traced, to ensure all the advantages of their situation; and while the usual principles are kept in view, of good flanking defences for the ditches; the works being mutually within the range of musketry; the various works keeping their proper and suitable command over each other; the communications being safe and easy, &c.: yet the whole should yield its usual regular form to the localities of the ground. Hence it is manifest, that under the great variety of ground to be met with, no further general rules can be given.

Defilement.

332. The second cause for a change in the regular forms of the works of a fortress, especially in the relief, is the influence of heights, upon which an enemy might establish himself within the range of artillery; and from which he could enfilade and take in reverse the works exposed to his view below.

Now the works can, in some cases, be so arranged as to neutralize the decided advantage that an enemy would possess from such a position; and this arrangement is called defilement.

333. There are circumstances, however, in which no arrangement of the works can screen or defilade them from heights: the first case is, when the ground to be fortified is encircled by heights, from which the assailant commands every part of the interior: and the second is, when hills are high, on more than two sides, and within a thousand yards.*

334. Defilement, therefore, refers to the arrangement of works which neutralize the advantages of moderate heights on one or two sides, when those heights are within the effective range of cannon.

335. In order that the advantages of height of situation may be understood, let fig. 200 represent the section of a square redoubt, having two of its faces, *S* and *R*, parallel to the range of hills c; and the other two faces (when prolonged) falling on the hills, which are supposed to be within the effective range of cannon: then a battery established on the hill, as at *c*, can take the defenders of the rear face *R* in reverse, and enfilade the whole length of the side faces (one of which is seen in elevation in fig. 200, *g f* to *h i*); hence the defenders immediately in rear of the parapet of the front face *S*, parallel to the hills, are alone screened; the revêtement, likewise, of this face is seen much lower down than it would be on a plain (as is indicated by the line of fire *c a*). Now, let it be supposed, in fig. 201, that the height *b c* is equal to *b c* in fig. 200; and that the dimensions of the redoubt in fig. 201 agree with those in fig. 200; but that the shape of the two ranges of hills differs, as seen in the figures; the

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* Although the point blank range of a 24-pounder is even under six hundred yards, yet it can batter with tolerable effect from eight hundred to one thousand yards; and a battery of iron 24-pounders, placed on commanding ground, at the Siege of St. Sebastian in 1813, had considerable effect at a distance of one thousand five hundred yards, in taking the works of one front in écharpe.—Sir John Jones's Sieges, vol. i. page 481.

one terminating abruptly in the plane, as in fig. 200; and the other being a long featured gentle slope, as in fig. 201: in the latter case, a simple inspection of the figure shows that the redoubt does not labour under any of the disadvantages of the former, and is precisely under the same circumstances, (as far as the hill *e* is concerned), as if the whole were on a level plain: this arises from the plane of site *omc* passing through the crest of the hill: and in fig. 200, the same result would be obtained, if the plane of site were made to agree with the line *digc*, instead of being as it is on the line *dab*.

Hence the principle of defilement is deducible, which is, to cause the plane of site to pass through the summit of the adjoining hills: thus in fig. 200, the terre-pleine of the interior must be raised to agree with a plane several feet higher than, and parallel to, *ig*; and the terre-pleine of the covered-way be raised from *p* to *r*.*

Now the chief objection to this arrangement is the great quantity of soil and labour, as well as time, necessary to form this remblai: all of which increase in an immense ratio with the proximity and height of the neighbouring hills.

If, in order to lessen this great remblai, in fig. 200, it were attempted to seek a plane of site parallel to, and lower than, *c d*, then the flank and rear faces of the redoubt (but especially the latter) would not have the necessary command over the ground on which they look: therefore the new plane of site should pass through the summit of the heights and the terre-pleine of the most distant works from them, that these works may preserve their proper command over the country before them.

336. It is to be remarked, however, that if even a fortress were defiladed on the principle of its plane of site thus passing through the summits of the heights on one or more sides, this arrangement gives an advantage to an assailant who might form his attack against the fronts farthest from the hills; as in approaching from the plain the defiladed works all slope downwards towards it, they would be subject to precisely the same disadvantages, as if they were commanded by heights. For instance, as in fig. 201, if the ground on the side *N* were horizontal, and an enemy approached by it, all the sloping works of the redoubt (such as *lk*) are fully exposed to his view, and liable to be enfiladed and taken in reverse. Hence this mode of defilading is suited only for a place susceptible of attack on the fronts facing the hills towards the summits of which the works slope: such as a fortress situated on the sea coast, or having marshy or inaccessible ground on its flanks and rear.

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* For figs. 200 and 201, the compiler is indebted to Colonel Pasley's Elementary Fortification.

337. Again, supposing that the works constructed on the inclined plane, as in fig. 201, answered the required purpose of shielding them from the parallel range of hills in front; this would be of no avail if the features of the range projected to the right or left, and commanded the interior of the works: thus in fig. 202, plate 13, the defilading of the works to neutralize the effects of the hills *R*, would not serve to screen them from the effects of an enemy's establishment on the heights *Æ*.

It would then become necessary to find a general *sloping* plane of site that would pass through the summits *R* and *Æ* and the terre-pleines of the works farthest from them; a proceeding that, in most cases, would tend greatly to increase the remblai, and consequently the labour, expense, and time of construction: and allowing that this could be effected when the hills are on two sides and of a moderate height, yet it is an arrangement that must stop there; for it could not be extended to works on a piece of ground having hills on more than two contiguous sides.

338. Now, suppose that it were required to defilade the fortress, *A*, fig. 202, plate 13, situated near the sea from a range of hills *R* parallel to the coast, and rising to a height of eighty feet at about a thousand yards from the enceinte on that side: (the hills *Æ* are not supposed to exist in this hypothesis).

By considering the figure it can be seen that the ravelins *B* and *C* and the covered-way before them, together with great portions of the covered-way before the bastions *I*, *H*, *G*, *F*, are all shielded from the effects of reverse fire from the hills *R* by the general mass of the ramparts of the body of the place (*I*, *K*, *H*, *L*, *G*, *M*, *F*,), which rises between these outworks and the hills: it would therefore suffice to give to *the glacis and ravelins* on these fronts next to the level country and to the sea, such a profile as would ensure their acting efficiently on the ground before them, and in support of each other; without reference at all to the heights *R* from which they cannot be seen.

But in order to defilade *the whole of the enceinte* and those outworks that are seen from the hills, their terre-pleines produced should cut the summit *R*, and their planes of defilement must respectively pass above them at the number of feet necessary to secure a proper command over the neighbouring country, as well as a mutual support amongst themselves.

To illustrate this in a general way, let fig. 203 represent a section taken on the line *L Z R* of fig. 202, (plate 13); it is here supposed that part of the body of the place *H L G*, next to the sea, is merely enclosed with a good parapet having a revêted scarp and counterscarp; hence the point *L* at the foot of the parapet is on the natural level of the ground: let a line be drawn as in fig. 203, from *L* to *R* to represent *the general plane of site for the enceinte* with which the terre-pleine *Z* in the plan and profile must agree.

Now, under the supposition that the hill *R* is at one thousand yards from the terre-pleine *Z*, and at one thousand four hundred and fifty yards from *L*; then in fig. 203, there are two similar triangles *L S R* and *L P Z*, of which we have *L S*, *S R*, and *L P* given to find *P Z*: that is,

$$LS : SR :: LP : PZ;$$

or 4350-ft. : 80-ft. : : 1350-ft. : 24·8-ft.

The terre-pleine of the enceinte at *Z* must therefore be 24·8 feet above the level *L P*, in order that the general site of the terre-pleine of the body of the place *Z L* may, when produced, cut the summit *R*: this will exceed the usual profile on level ground by about 10 feet.

We have here a height of 80 feet *S R*, fig. 203, on a distance of 1450 yards *L S*; that is, a depression of about ·66 of an inch to every yard in length: consequently such portions of the enceinte as are nearer to the hills than *Z T*, must slope up towards *R* in this proportion; and such as are nearer the sea than *L X* must be still lower than *L* in the same proportion; although the latter arrangement need not be carried into effect as the bastion *H* and *G* are so far removed from the enemy's batteries at *R*; and could readily be covered by *pare-a-dos* or traverses.

It is proved, therefore, that the terre-pleine at *Z* should be 24·8 above the level of the ground; let a plane of defilement pass above this at 7·5 feet which will fix the crest of the parapet at 32·3 feet above *P*.

As the ground between *R* and the glacis *O* is flat, and as the terre-pleine of the covered-way at *O* must necessarily be several feet above the natural level of the ground, the enceinte and ravelin should have a good command over the covered-way and country: the following would be about the relief of the works on the section seen in fig. 203.

Crest of the enceinte above the level of the ground		32·3 feet.
Ditto of ravelin	ditto . .	24
Ditto of glacis	ditto . . .	16
Terre-pleine of the enceinte above the level of the ground		24·8
Ditto of the ravelin		16·5
Ditto of the covered-way		8

In order to cover the revêtements from any injury from batteries on *R*, it would be necessary to make the exterior slopes of the parapets of the body of the place and of the ravelin, longer than usual:* therefore to procure a proper height of revêtement, the depth of the ditches on the line *L S* would be nearly as follows.

Depth of the main-ditch below the level of the ground, allowing 18 feet for the exterior slope of the parapet, and a height of scarp revêtement of 30 feet. 15·9 feet.

Depth of the ditch of the ravelin below the level of the ground, allowing 12 feet for the exterior slope of the parapet, and a height of scarp revêtement of 24 feet . . . . 12 feet.

And if the terre-pleine of the covered-way be sloped away three feet to the rear in its whole width, there would remain a counterscarp revêtement of seventeen feet.

From this it is evident that the soil excavated from the ditches could not furnish the masses required for the remblai, the procuring of which, elsewhere, would greatly increase the expense.

339. One imperfect section is here given (fig. 203) to convey a partial idea of the subject; but a view of sections, however numerous, would be unfit to exemplify the arrangement of defilading; as their dimensions would change at every foot of ground: hence the usual mode of showing the properties of a fortress by a plan and profile would fail to convey just ideas of defiladed works; and to elucidate their varying dimensions, it has been recommended to survey, with great accuracy, the spot to be fortified, and all the surrounding country, to a distance of 1,500 yards; to fix a horizontal plane for a level, and to mark, with great care, every deviation from it in the irregularity of the ground. This horizontal plane, most of the French engineers

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* The disadvantages of a fausse-braie have been already pointed out, paragraphs 136 and 137; but if any thing could sanction such a construction, it would be in the case of a commanded work, when such an arrangement would tend to hide the scarp revêtements from the enemy's view on the heights, not only by the unusual length of the exterior slope of the inner parapet, but by the upper revêtement being covered by the mass of the parapet of the fausse-braie.

cause to pass at a certain distance above the highest ground; consequently in plotting the uneven surface of the country on paper according to the number of feet below this *plane of comparison*, the highest ground bears the lowest numbers, and the lowest ground is marked by the highest numbers, as in a naval chart: but Colonel Pasley recommends (as well as Bousmard) that this guiding plane should be lower than any ground to be included in the limits of the intended works; for instance, when near the sea, low water mark to be the plane of comparison. Then the numbers plotted upon the plan would correspond with the actual elevation and depressions of the ground.

When correctly performed, this *plan of comparison* or *modelling plan*, gives a thorough knowledge of the ground at a glance, and is quite necessary to aid in the arrangement, calculation, and the execution of the works.

When completed with all the details filled in, let lines be drawn on the several fronts, perpendicular to the crests of the respective works, bearing on each slope, ditch, &c., its elevation above, or depression below, the plane of comparison, in feet and inches; and they will serve as so many illustrative sections.

340. By examining fig. 202, it is clear that if there were any natural rise of ground, running from *I* to *F*, sufficient to hide all between it and the sea from the view of hills *R*, there would be no necessity to attend to defilading the works thus protected: and the general sloping of the works towards the hills need only commence from the spots where the rise is of no more avail in sheltering them: and in such a case, if the fortress had a level plain of ground on the side where the sea is supposed to be in these figs. 202 and 203, (*Y*), all the works between the supposed rise from *I* to *F* and this plain could have the usual profile given them in order to meet any attack formed on that side: and in defilading the works on the hill side of the rise, no evil could follow; on the supposition that the rise from *I* to *F* would act as a great *pare-a-dos* and traverse against any attack conducted on the side of the plain.

But as such a natural rise of ground rarely exists, it has been found that the masses of buildings which usually fill up the interior of fortresses have been sufficient traverses and parados: yet this is a species of protection that should be very scrupulously taken into account, by any scientific man charged with the original arrangements of defilading a place from heights.

Much may be done, however, by cavaliers and traverses, judiciously combined with defilading: for example, if cavaliers were placed in the bastions *I* and *F* as indicated by the dotted lines *V V*, figs. 202 and 203, they would greatly serve as screens from the hills, to the works beyond them: indeed, if it be necessary to render the fronts farthest from the hills, capable of sustaining an attack, cavaliers and traverses must be formed to serve as parados to each half of the fortress.

341. By referring to figs. 202 and 203, it may be seen that *R* is an under feature running out from a still higher hill *Q*; but the works are defiladed from *R*, because *Q* is supposed to be at such a distance that artillery placed upon it could act but feebly, if at all, against the place: hence the process of defilading is not with reference to the highest ground within the extreme range of artillery, but with respect to the ground nearest to the place from which artillery could plunge its fire into, and act most fully against, the works. It is true that the defenders must submit to the inconvenience of being seen from *Q*; but this is not a matter of sufficient moment to authorize the expenditure of means and time in defilading the interior of the works from the height: a little height, therefore, near to the works, is more to be feared than a great height beyond the range of artillery.

342. From what has been here briefly set forth, and from the intricacies and expense that the execution of defilading manifestly involves; it follows, that in proportion as the hills surround and near the place, these difficulties become greater and greater, till at length, defilement becomes impracticable, and parados, traverses, retrenchments, and casemated batteries on the commanded fronts, can alone compensate for such disadvantages.

343. From the great elevation of the works, as shown on the section *L Z*, fig. 203, facility is thus given for advantageously constructing advanced works between the foot of the hill *R*, and the glacis of the place; which would there be fully submitted to the command of the superior works in their rear, without masking the effect of their fire.

344. In tracing the works that have to be defiladed, great care should be taken that as few as possible of the prolongations of the faces should fall upon the commanding ground, from which the assailant could enfilade and ricochet them; thus, in fig. 202, the right face of the bastion *E*, and the left face of the bastion *D*, could be easily enfiladed from the heights on which their prolongations fall; whereas, the faces of all the other works have their prolongations clear of the hill; and the defiladed defensive masses being generally higher and more solid than common profiles, the artillery of the attack would have more difficulty in bringing their enfilade and ricochet batteries into full play, from the low ground.

345. By examining figs. 202 and 203, it will be observed that in proportion as *Z* is distant from *L*, and nearer to the hill, the height *P Z* will increase, and with it the general remblai, the difficulties, and the expense of the construction: and vice versa—that is, as the distance between *Z* and *L* is lessened, and the works removed from the hill, the height *P Z* will decrease, and the construction become more simple and less laborious.

Now, if the purpose for which the fortress *A* is constructed, can be equally answered by lessening the distance from *Z* to *L*, and making it more oblong, by occupying ground in the directions *F* and *I*, it would certainly be a preferable arrangement, as it would decrease the general remblai, &c.; as has just been shown.

Hence, a position having little depth (such as works situated on the edge of the sea, or on the banks of a defensible river) would not be so difficult to defilade from moderate commanding hills running parallel to it, as an equal quantity of ground under a like disadvantage of command, but occupying more depth, and thus approaching nearer to the hills.

The example supposed in figs. 202 and 203 is one which would be rarely applied in practice; it is introduced merely to illustrate the subject. For in most cases it would be desirable to erect a low rampart on the front *L*, so that the plane of site *L R* would appear as the line *cd* in fig. 200; an arrangement which would of course augment the general dimensions of the whole; unless by parados, traverses, and other means, the fronts between *F* and *I* and the sea were covered; and the defilading commenced from the centre of the fortress towards the hills, which would probably be the least expensive and most efficient proceeding.

346. In conclusion, the following passage is added from a note by Sir John Jones at the end of his first volume of the Sieges in Spain.

" But if the hills are of a great height and near the place, the mischief arising from their command cannot be obviated by defilement, and even in many cases where it is possible to effect the defilement, the great labour and expense of so doing, put it out of the question. Under such circumstances, the best resources are casemates and countermines; or to occupy the summits of the commanding hills by works of sufficient strength to restore the equilibrium of defence; such for instance as Fort Montjuic at Barcelona, Gonzaga and Castelacio at Messina, and La Lippe at Elvas, which even render the side commanded the strongest of the place, and such will be the work constructing at this moment (1827) on Mount Feron at Ath.*

" * This latter remedy for command costs the engineer so little trouble to plan, and is so generally approved, that a redoubt placed on the summit of any commanding height is a becoming sort of panacea to neutralize the effects of command. It should, however, never be resorted to except where the heights are close to the fortress, say within 600 yards, or that the resources of the engineers' art prove unequal to obtain an equilibrium of defence, by a superiority of construction of the fronts

"There remains a disadvantage still to be mentioned, accruing to a place from being commanded, which is, that a besieger's first batteries, placed on the height which commands it, may remain open to the last moment of the attack without incommoding his near approaches: but when the height falls rapidly in one continued plane to the glacis of the place, this advantage is much counterbalanced by the difficulty mentioned in the former note, of carrying approaches down hill; and should the fall of the ground be gradual, it will frequently happen that the fire of the batteries on the height will prove almost as annoying to those in the advanced part of the trenches, as to the defenders of the place.

"Works placed on very elevated situations, on the summit of steep hills, give them an imposing appearance: but is in reality a defect highly prejudicial to their efficiency and defence, for the fire of their artillery on the object to be guarded becomes so plunging as to lose half its powers: the musketry cannot be made to scour the face of the hill sufficiently; and during the night both arms become of most uncertain effect; and in order

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of the enceinte commanded by the height: for advanced works cost more in their construction, and add more to the ordnance stores and men required for the defence of a fortress in proportion, than a similar degree of strength gained for a place by additions to the enceinte, for they must be most complete in every defensive detail; and unless their communications be extremely well secured, they must, when near the theatre of operations, be kept fully manned to secure them from being surprised, and be furnished with a full proportion of everything necessary for their own defence, and when vigorously attacked, they are seldom capable, from want of space, of making a protracted resistance.

"Who has not observed, whilst examining fortresses in hilly countries, (Genoa for instance) that advanced fort after advanced fort, thrown up to occupy hill after hill, and requiring an army for their occupation, might have been dispensed with, and the place increased in strength, if one half the labour, thus scattered over miles of country, had been judiciously confined to strengthening and securing the commanded fronts."

to command the face of hills, flèches or small redoubts must be established in front of the main work on the projecting knolls that afford the best flanking points. This arrangement, however, does not answer so well as the main works being placed on a height of more moderate and regular ascent, which shows that very elevated situations are seldom to be preferred."*

347. *Defilement for field works.* In field fortification, the limits of defilement are regulated by the range of field artillery and musketry: for the former, the horizontal distance is eight hundred yards, the vertical one, four feet; being nearly the height of the axis of a field piece; for the latter, the horizontal limit is three hundred yards, and vertically eight feet; for eight feet is considered the extreme height of the crest of a parapet, over which the assailants fire.

In an enclosed work, the interior space is limited by the projection of the crests. Open works are generally defiladed to a distance of twenty yards in rear of their gorges, and the curtains of redan or bastioned lines to the same distance in rear of their crests.

In no case should the interior slopes of the parapets be discoverable from without; whence arises the necessity of traverses to protect the defenders from enfilade, slant, or reverse fire; when intended for the latter purpose they are called *parados.*

348. *Practical methods of defilading field works.*

To defilade from artillery.

The plane of defilement, *A C,* fig. 204, should pass four feet above the height *H,* and eight feet above the point *B,* taken near the gorge of the work to be defiladed. The plane *D H,* parallel to the plane of defilement, and tangent to the point of command H, may be considered as the plane of site. This plane cuts the vertical AB in the point D, four feet above the level of the ground; to apply this in practice, for example, to a lunette:

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* Sir John Jones's lines of Torres Vedras.

After having planted poles at the angles of the lunette, fig. 206, and stretched a cord mn four feet above the projection of the gorge, hold a straight edge ab between two pickets driven a few yards in rear of the work, and elevate and depress the edge ab, till it and mn are both in a plane tangential to the height H.

If, then, the eye of the observer be placed at any point in the line ab, the visual ray EH, drawn on that plane through the pole at the salient angle of the lunette, will show the height of the plane of site at the point C. In a similar manner, the point D at the angle of the shoulder, or any other point required, may be found. To each of the heights so obtained add four feet and saw off the poles at that height: their summits will then show the relief of the work required.

If this relief should, however, exceed the maximum height of twelve feet allowed for field works, it can be reduced by lowering the line mn a foot and a half, which will still leave a relief of six feet and a half at the gorge. If this should not be sufficient, recourse must be had to traverses.

349. *To defilade from musketry.* When the points of command are within the range of musketry, or three hundred yards, of the works, the plane of site must pass through the foot B of the pole, fig. 205, placed at the gorge of the work, for the height CH, (that of a man firing over a breastwork) from which it is necessary to be defiladed, is equal to that AB at the gorge, that is eight feet.

There would be difficulty for the observer to fix the plane BH, fig. 205; but if BD be made equal to one foot and a half, the eye of the observer can then ascertain the direction of the plane: to determine the plane of defilement, complete the height at the gorge to eight feet, and set off from seven to seven feet and a half on the pole planted at the salient, above the plane DH, which will defilade the works sufficiently.

With the aid of a plain table, the plane of site can be accurately and rapidly determined. Suppose the upper surface to be directed to the points of command, the intersections of that surface prolonged, with the poles planted at the angles, fix the heights of the plane of site.

If it were required to be defiladed from two or more heights, then the plane of site, being at once tangent to two points of the surrounding ground, could not be made to pass through a given *line* at the gorge, as in the foregoing articles, but only through a *point* of that gorge; for example a point near the centre of it: which point must be raised four or eight feet above the plane of site, according as it may be required to defilade from field artillery or musketry.

Let *M* and *N*, fig. 207, be two heights from which it is necessary to be defiladed from artillery. In the centre of the gorge of the work, or at the point most distant from the heights, plant a pole standing four feet out of the ground. Before it place two others, *D* and *E*, and cause a straight edge or tightened cord to be moved up and down on them, until, when seen from the end of the four feet pole, it appears to touch at the same time both the points *M* and *N*: this will evidently be the plane of site; and to the height obtained by it, let four feet be added as before.

It often happens that a single plane of defilement would give too great a relief; the left part of the work must then be defiladed from the height *M*, and the right part from the height *N*: and as this would expose the faces to be enfiladed and seen in reverse, it becomes necessary to construct a traverse of a height and thickness sufficient to screen the troops when on the banquettes from slant or reverse fire: the traverse is usually made on, or nearly on, the capital; it should not be less than six feet thick at top, and, unless revêted, its slopes should be at 45°.

A triangle, constructed of smooth laths, (the ends halved into each other so that the upper and under surfaces may be parallel);

and each side of about a yard in length, is convenient to use to find the plane of site.

If a line at the gorge be given as *m n*, fig. 206, place one side of the triangle on this line, and move the apex until the surface of the triangle is a tangent to the commanding ground.

If a point near the gorge be given, fig. 207, place one of the angles of the triangle on the given point, and let the triangle revolve about that point until its surface is a tangent to the points of command.

The most simple mode of determining a traverse is to assume its position, and then to give it a sufficient relief to cover the men placed on the banquettes on each side of it. At the same time, the planes of defilement of the parapets should pass eight or six feet and a half at least, above the ground towards the centre of the traverse.

Let *A B*, fig. 208, be the axis of a traverse; *C D* and *E F*, the opposite parapets of a redoubt to be defiladed from musketry. On the side of the plain, the parapet *E F* will be eight feet high, but the relief of the parapet *C D*, on the other side, will be determined as shown in fig. 205; so that the plane of site may pass eight feet above the ground, in the direction of the axis of the traverse.

Then find two lines of fire, *P c* and *M e*, so that they may pass two feet above the parapets *D C* and *E F*, which height is required, in order that the shot may be intercepted by the traverse, or pass above the heads of the troops mounted on the banquettes. The height of the traverse is then determined by that line of fire which gives the greatest relief.

For the first of the two lines (*P c* and *M e*) plant, at the point *L*, a pole eight feet high; measure on the pole *D C*, equal to two feet; the visual ray, passing through the points *P* and *c*, will be the line of fire sought.

The other line of fire may be determined in a similar manner.

Having thus found the relief of the traverse required to cover the widest part of the work, and its command over the parapets being known for that part, let the same command be preserved throughout.

These constructions, though simple, require some time; where then an opportunity does not offer of determining accurately the dimensions of the traverse required to defilade a work, make it one yard higher than the parapet, and the work will, in most cases, be perfectly covered.*

351. Fig. 209 shows the mode of defilading field works under various circumstances. The hill *A* is situated rather to the right of the redan below it, consequently an assailant upon it would see its left face in reverse, to screen which the traverse *e* is made nearer the left than the right face. The hill *B* equally commands the right and left faces of the redan beneath it; the traverse *f* is therefore made high enough to defilade both faces. The hill c commands the square redoubt below it, looking in reverse upon its rear face, to protect which the traverse *g* is erected: the hill *D* commands the square redoubt below it in front and on either flank, to neutralize which the cross traverses *h* and *i* are raised: in the two latter cases, the rear faces are to have a sufficient command over the country before them.

352. *Construction of Vauban's first system.* See fig. 14. Make the angle of the polygon of the required opening; and each of the exterior sides equal to one hundred and eighty toises; bisect the latter by the right radii; and on each front proceed as follows: on the right radius, inwards from the exterior side, lay off the perpendicular (for a square, one-eighth of the exterior side; for a pentagon, one-seventh; for a hexagon, or polygons of a greater number of sides, one-sixth). From the angles of the polygon, draw the lines of defence through the inner extremity of the perpendicular; and on these lines, lay off two-sevenths of the exterior side from the angles of the polygon, for the faces of the bastions: these points mark the shoulder

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* This information on the deflement of field works is chiefly drawn from Colonel Dufour's Course of Fortification.

angles of the bastions, and, with a distance equal to the interval between them, describe arcs intersecting the lines of defence; chords to these arcs give the flanks of the bastions; and a line joining the inner extremities of the flanks will give the curtain.

To trace the main-ditch, describe an arc of a circle from the flanked angle of each bastion, with a radius of fifteen toises when the ditch is dry, and eighteen toises when it is wet; lines drawn as tangents to these arcs from the shoulder angles of the collateral bastions, give the counterscarp.

To trace the ravelin, set off fifty toises from the re-entering angle of the counterscarp of the main-ditch, along the right radius, in order to fix the flanked angle of the ravelin; from this point, the faces are directed to points at five toises from the shoulder angles of the bastions in the rear, taken along the faces.

The faces of the tenaille coincide with those parts of the lines of defence that lie between the flanks of the bastions; its thickness is eight toises; its extremities, or profiles, are parallel to the flanks of the bastions, at a distance of four toises; and its rear is parallel to the curtain at five toises.

To trace the caponniere, draw its crest parallel to the perpendicular at three toises; and its glacis at ten toises parallel to its crest; the passage between the demi-gorge of the ravelin and the head of the caponniere is nine feet wide.

The breadth of the covered-way is five toises, following the windings of the counterscarp of the ditches; at the re-entering angles, set off fifteen toises on each side, as demi-gorges for the place of arms; at these points, the faces are to form angles of 100° with the original tracing of the covered-way; the foot of the glacis is parallel to its crest at twenty-five toises.

The traverses are three toises thick; those at the salient places of arms, are formed on the prolongations of the faces of the ravelins and bastions; those at the re-entering places of arms are perpendicular to the covered-way: each branch of the covered-way before the ravelins, has a third traverse, placed mid-way between the salient and re-entering places of arms.

The passages around the traverses are formed so as to leave a clear space of nine feet, free of all the slopes.

To fill up the details of the first system; according to figs. 13 and 14; the horizontal breadth of the slopes are as follows:

		feet.
For the covered-way:	interior slope of the parapet . .	1½
	banquette . . .	5
	slope of ditto . .	6
For the traverses:	exterior slope of the parapet . .	5
	superior slope ditto . .	18
	interior ditto ditto . .	1½
	banquette . . .	5
	slope of ditto . . .	6
For the ravelin:	outwards from the cordon for the revêtement	6
	inwards from the cordon, for the exterior slope of the parapet . . .	9
	for the superior ditto	18
	interior ditto	1½
	banquette	4½
	slope of ditto	6
	terre-pleine of the rampart . . .	18
	interior slope of ditto	11
For the tenaille:	outwards from the cordon, for the revêtement	3½
	inwards from the cordon, for the exterior slope of the parapet . . .	4½
	for the superior slope of ditto . .	18
	interior slope of ditto . .	1½
	banquette	4½
	slope of ditto	6
For the caponniere:	the interior slope of the parapet .	1½
	banquette	5
	slope of ditto	6

	feet.
Enceinte: outwards from the cordon, for the revetêment	6
inwards from the cordon, for the exterior slope of the parapet	12
for the superior ditto	18
interior ditto	1½
banquette	4½
slope of ditto	6
terre-pleine of the ramparts	24
interior slope of ditto	14
The horizontal breadth of the counterscarp revêtement in rear of the covered-way, is	4

The staircases at the re-entering places of arms are thirty-six feet in length, and six feet in breadth; those at the salient places of arms before the bastions are of like dimensions; but before the ravelins, where the space between the traverses, is more limited, the staircases are steeper; having a length of twenty-four feet, and a breadth of six feet: they are constructed according to the directions contained in paragraphs 86 to 88.

The profiles to the traverses are constructed on the principles detailed in paragraphs 81 to 83; the outer end of the traverse being supported by a field revêtement, having a base equal to one-fourth of the height; and the inner end by the counterscarp revêtement wall being built up in continuation of its slope; the base one-fifth of the height.

The banks of earth forming the sides of the ramps or sally-ports leading out of the re-entering places of arms, as well as those that support the extremities of the banquettes, &c., have a base one-fourth of their height.

The ramp along the interior slope of the rampart of the ravelin is ten or twelve toises long, and two toises wide; that at the gorge of the full bastion, as well as the flank of the empty bastion, is seventeen toises long, and three toises wide: to be constructed on the principles laid down in paragraph 89.

The breadth of the gorge revêtement of the ravelin is four feet; the stair cases are thirty-six feet long, and six feet wide.

The breadth of the gorge wall of the tenaille is three feet: the stair cases thirty feet long, and six feet wide.

The barbettes, at the salients of the ravelin and bastion, have at least a width of twenty-four feet of platforms for the service of the guns, with easy ramps leading from the terre-pleine of their ramparts.

The embrasures to defend the ditches of ravelin have their lines of fire parallel to the sides of these ditches: those in the flanks are parallel to the lines of defence.

In order to construct a set of profiles to this system; it is only necessary to give the commands of the various works, and the depth of the ditches; since the horizontal breadth of the slopes, have just been detailed.

		feet.
The command of the enceinte	over the country is .	22½
ditto	over the ravelin . .	3
ditto	over the crest of the glacis	14½
ditto	over the tenaille . .	21
The depth of the main ditch below the level of the ground		22
ditto of the ditch of the ravelin ditto . .		22
The command of the ravelin over the crest of the glacis		11½
The crest of the glacis above the ground . . .		8

The plane of defilement for the revêtements is to coincide with the crest of the glacis; which therefore gives a height of scarp revêtement for the enceinte, and for the ravelin, of thirty feet; the revêtements to be of the common construction, having a slope to the front of one-fifth of their height: the counterforts are to be eighteen feet apart; of the diminished form; and of Vauban's dimensions as laid down in paragraph 186. The pupil is left to fill up the details of the profiles from the information contained in definition 24: in paragraphs 114 and 117.

The section of the posterns may be taken on the lines 9, 10, 11, of fig. 14; as shown in figs. 54 and 55.

353. *Construction of the modern system—see fig.* **210.**—The exterior side of the polygon is one hundred and eighty toises: the perpendicular is one-sixth; and the faces of the bastions one-third of the exterior side: the flanks are perpendicular to the lines of defence upon which they fall, making the angles of defence, right angles. The main ditch is fifteen toises wide at the flanked angle; and the counterscarp is drawn to the shoulder of the parapet of the next bastion.

For the ravelin: set off seventeen toises from the shoulder angle of each bastion, along the face; join these points, which gives the base of an equilateral triangle, having its vertex, on the right radius, for the flanked angle of the ravelin: its ditch is ten toises broad.

The face of the redoubt of the ravelin is drawn parallel to that of the ravelin from the shoulder angle of the parapet of the bastion; its ditch is five toises wide, which leaves the ravelin ten toises and a half thick; divide this thickness at its extremity into two parts, and join the points of division for the gorge of the redoubt of the ravelin; this redoubt has flanks; they are traced by setting off eight toises along the gorge, and with a radius of nine toises from thence, cut the face, a line joining these points gives the flank. The caponniere is of the same dimensions as in the first system, running up to within nine feet of the gorge of the redoubt of the ravelin.

To obtain the cavalier; draw the faces and flanks parallel to the magistral of the bastion, at a distance of twelve toises: on the faces, these lines will show the counterscarp; and on the flanks, the foot of the exterior slope of the parapet: the ditch, on the faces, is five toises wide, drawn inwards from the counterscarp: there is no ditch on the flanks; these flanks are fourteen toises long.

For the coupure, or cavalier retrenchment; raise perpendiculars to the faces of the bastions from the points marked seventeen toises from the shoulder angles, for the counterscarps of the coupures; the scarps are five toises parallel to them:

behind this short scarp there is a parapet, with one embrasure for the defence of the terre-pleine before it; the ditch of the cavalier is defended by a parapet retired from the coupure, having two embrasures.

For the covered-way: trace the crest of the glacis at five toises parallel to the general outline of the counterscarp. For the redoubt in the re-entering place of arms, bisect the re-entering angle of the counterscarp of the covered-way by a capital; join the flanked angles of the bastion and ravelin together, and the portion of this line intercepted between the capital and the counterscarp, gives one face of the redoubt; the other is drawn from the meeting of the branches of the covered-way of the salient places of arms before the bastion, through the flanked angle of the redoubt, till it meets the counterscarp of the ravelin. The scarp is fifteen feet parallel to the counterscarp.

This redout has a flank of fifteen feet in length at the end of its parapet, on the side adjoining the ravelin; and here its demi-gorge is formed by a line drawn from the flanked angle of the ravelin through the inner extremity of its flank; by which a small triangular space is added to the ditch of the ravelin.

Set off seven toises and a half from the extremity of the counterscarp of this redoubt, along the counterscarp of the ravelin; with a radius extending to this point, from the original re-entering angle of the counterscarp, as a centre, describe a curve outwards, for the crest of the re-entering place of arms; the traverses at the entrance to the latter are three toises thick; on the branches before the ravelin there are three traverses, each nine feet thick, and the passages are en cremaillère (paragraph 52 to 55).

The crest of the parapet at the salient place of arms is cut off perpendicularly to its capital to give a banquette of eighteen or twenty feet for the purpose of obtaining a direct fire upon the ground before the capital.

In order to obtain the coupure or retrenchment in the ravelin, let fall a perpendicular from the extremity of the counterscarp of the redoubt in the re-entering place of arms, to the face of the ravelin; this line crossing the ravelin gives the counterscarp of the ditch of the coupure; the scarp of which is fifteen feet parallel to it, having a parapet behind it in order to bring a fire upon the terre-pleine of the ravelin.

To fill up the details of the modern system; the slopes of the traverses and those of the covered-way, correspond with like works in the first system of Vauban, as already given.

	feet.
The parapet of the redoubt in the re-entering place of arms has its exterior slope equal to	6
superior ditto	18
interior ditto	1½
banquette	4½
slope to ditto	6
The ravelin has the exterior slope of the parapet.	6
superior ditto	18
interior ditto	1½
banquette	4½
slope of ditto	6
The redoubt of the ravelin—exterior slope	6
superior ditto	18
interior ditto	1½
banquette	4½
slope of ditto	6
terre-pleine of the rampart	18
interior slope of ditto	10
The tenaille—exterior slope of the parapet	6
superior ditto ditto	18
interior ditto ditto	1½
banquette	4½
slope to ditto	6
Caponniere—interior slope	1½

		feet.
Caponniere—	banquette	5
	slope to ditto	6
Enceinte—	exterior slope of the parapet	12
	superior ditto	18
	interior ditto	1½
	banquette	4½
	slope to ditto	6
	terre-pleine of the rampart	24
	interior slope ditto	14
Cavaliers—	exterior slope of the parapet	12
	superior ditto	18
	interior ditto	1½

At the extremity of each face of the cavalier, there is a ramp ten toises long and two toises wide, in order to descend from its terre-pleine to that of the enceinte; the width of the latter in rear of the cavalier is twenty-one feet.

In filling in the slopes of the ravelin and of the bastion, care must be taken to leave the ditch of the coupures vacant; here the thickness of the revêtement wall alone is shown: see note to paragraph 147.

Communications.

The ramps leading from the covered-way through the glacis, in the re-entering places of arms, are of a curved outline to prevent their being enfiladed.

The counterscarp of the redoubt in the re-entering place of arms, is descended by a ramp seven toises long and one toise wide; a postern, six feet wide, is formed under the parapet to lead from the interior into the ditch.

Stair cases, six feet wide, parallel to the demi-gorges, communicate to the ditch of the ravelin and to the main ditch.

Ramps, twelve toises long and two toises wide, lead from the ravelin to the ditch of its redoubt: and a staircase communicates from the latter into the space behind the coupure.

A postern leads from the ditch of the redoubt of the ravelin, through the middle of the flank, into its interior.

Staircases lead from the main-ditch at the head of the caponniere into the redoubt of the re-entering place of arms.

Posterns, as in the first system, communicate from the interior of the place through the curtain into the main-ditch; and also through the tenaille.

The usual ramps are formed in the interior slopes of the ramparts, in the redoubt of the ravelin, and in the enceinte.

In filling up the details of this plan, barbettes (of suitable dimensions) may be shown at the flanked angles of the parapets of the bastions and ravelins; their faces armed with artillery, having traverses between every two guns, on the principle detailed in paragraph 261.

The cavalier has nine embrasures on its face, and three on its flank, respectively perpendicular to these lines.

In order to obtain a set of profiles explanatory of the modern system; the following information is given; see figs. 210 and 211.

The horizontal breadths of the slopes have just been given.

	feet.
The crest of the glacis at the salient place of arms before the ravelin, above the plane of site is . . .	9
Ditto ditto at the re-entering place of arms, ditto . .	11
The terre-pleine of the covered-way in the latter case is three feet, and in the former one foot, above the plane of site	
The main-ditch below the ground line is	24
The ditch of the ravelin ditto	18
Ditto of the redout of the re-entering place of arms ditto .	8
Ditto of the redoubt of ravelin ditto	6
Crest of the redoubt of the re-entering place of arms above the level of the ground	16
Ditto ditto of the ravelin ditto	16
Ditto ditto of the redoubt of the ravelin ditto . . .	18
Ditto ditto of the tenaille ditto	4

	feet.
Crest of the enceinte, above the level of the ground	22
Ditto ditto of the cavalier ditto	31

The revêtement walls are all perpendicular in front, having the slope to the rear; the thickness of these walls at top is as follows:

	feet.
Scarp of the cavalier	5
Counterscarp ditto	3
Scarp of the enceinte	5
Counterscarp ditto	3
Scarp of the redoubt of the R. P. A.	4
Counterscarp	3
Scarp of the tenaille	4
Gorge of ditto	3
Scarp of the redoubt of the ravelin	4
Counterscarp	3
Scarp of the ravelin	5
Counterscarp	3

In order to get the slope to the rear, or the thickness of these walls at bottom, divide the total height of the wall by 6, and add the product to the thickness at top. To obtain the length of the counterforts take $\frac{1}{3}$ of the height of the revêtements respectively: the counterforts are diminished, the thickness at the root being $\frac{1}{5}$ of the total height; and half of this for the thickness at the tail.

354. *Construction of Vauban's third system:—as executed at New Brisach—see fig.* 212; *also the note to paragraph* 157.—(The works are conveniently constructed upon an octagon). Make the exterior side one hundred and eighty toises; the perpendicular one-sixth, and the faces of the bastions one-third, of the exterior side; the flanks are obtained by describing arcs of circles from the shoulder angles of the bastions with a radius equal to the distance between them, to intersect the lines of defence,—chords to these arcs, give the flanks of the great

bastions or counterguards: (these bastions are not connected to each other by curtains as in the first system of Vauban, and in the modern system): a straight line joining the extremities of the flanks of these counterguards, and produced till it meets the oblique radii, will fix the flanked angles of the tower bastions; a line drawn parallel to this at nine toises within it, will give the interior side, the extremities of which determine the centre of the tower bastions. On this interior side, lay off eight toises from the centres of the towers, and at these points, raise perpendiculars, on which take six toises outwards and four inwards for the flanks: the outer extremities of the flanks joined to the flanked angles, give the faces of the tower bastions. From the interior side, set off five toises inwards on the perpendicular, and through this point, draw lines of defence from the angles of the flanks of the towers; the flanks of the counterguards produced so as to cut these lines of defence, determine the flanks of the enceinte, and of course fix the faces and curtains of the body of the place.

The ditch of the enceinte is seven toises wide, described from the flanked angle of the tower bastions, and the counterscarp is drawn as tangents to the arc from the extremities of the flanks of the counterguards.

The profiles of the tenaille are at four toises from the flanks of the counterguards; and it occupies all the space between the flanks.

The main-ditch is fifteen toises wide, described from the flanked angle of the counterguard; and the counterscarp is a tangent to the arc, drawn from the shoulder angle of the collateral bastion.

The capital of the ravelin is fifty-five toises, set off from the re-entering angle of the counterscarp of the main-ditch; and the faces are directed upon the counterguards at points marked fifteen toises from the shoulder angles: the ravelin has flanks, to be obtained by setting off ten toises from the extremity of each face along the scarp, and from these points draw the flanks parallel to the capital.

The redoubt of the ravelin has a capital of twenty-three toises; its faces are parallel to those of the ravelin; and the flanks determined, in like manner, by setting off four toises and a half along the scarp from the extremities of the faces.

The ditch of the ravelin is ten toises wide, and that of the redoubt, five toises; the counterscarps being parallel to the scarps.

The covered-way, places of arms, traverses and glacis, correspond with those in the first system of Vauban.

To fill up the details of the third system, the following directions must be attended to.

The slopes of the parapets, banquettes, &c. in the covered-way and traverses, are the same as those detailed in the first system.

The ditches are wet; the revêtements at the counterscarps, and scarps of the great bastions and ravelins, are similar to those in the first system; the staircases in the counterscarp of the covered-way, that lead from the level of the water to the terre-pleine above, are constructed in the same manner as in the first system; as also in the gorges of the other works.

The ramparts and parapets, throughout, are of the usual dimensions; the ravelins and the counterguards have the chemin des rondes of ten feet in breadth (paragraph 141).

The redoubt of the ravelin, and the enceinte, have entire revêtements (paragraph 176).

The tower bastions are all of masonry; the slope of the entire revêtement is five feet; the parapet eight feet thick, with a banquette of masonry in its rear; the gorge is closed by a wall four feet thick, having a gateway eight feet wide in its centre. These towers have a command of two feet upon the counterguards; they have three embrasures in each face, directed so as to see the whole of the interior of the counterguards, to which they act as retrenchments; they have two embrasures in each flank, to aid in the defence of the ditch of the enceinte, which they command; they have casemates (paragraph 198) of an inferior description, the platforms of which are made one foot above the surface of the water in the ditch; these casemates are pierced with two embrasures in each flank, to aid the guns on the terre-pleine above, in the defence of the ditch of the enceinte; the supplementary or small flanks, in the front connecting the towers, have each two guns, one in embrasure above, and one in casemate below, looking into the ditch before them; so that six guns are provided as a defence for the ditch in rear of the counterguards.

Part of the casemate under each tower is formed into a magazine, the roof of which is built up solidly in the centre of the tower, to serve as a parados, thirty-six feet long, and six feet thick.

Posterns lead into the casemates, from the interior slope of the rampart of the enceinte.

Bridges, twelve feet wide, communicate from the enceinte to the great bastions, and are placed in the most secure and covered situation, running close to the flank of the towers: a postern leads from the interior of the enceinte to the inner end of the bridge; and a flight of stairs from the outer end to the interior of the counterguards.

Posterns pass through the middle of the mass of the flanks of the counterguards, to bridges that lead into the profiles of the tenailles; and ramps lead up to their terre-pleines.

Temporary bridges, twelve feet wide, run along the demi-gorges of the redoubt of the ravelin, and touching the extremities of the faces of the ravelin, they communicate to the staircases in the re-entering places of arms.

The defilement of the faces and flanks of the counterguards is as follows: the shoulder angle is kept three feet lower than the flanked angle, and the inner extremity of the flank one foot lower than the shoulder.

355. The compiler has already stated that his work is for the specific purpose of aiding an instructor and his pupils; it does not assume to set forth a comprehensive and perfect view

of all the approved systems; but a knowledge of the contents of this volume, will suffice to prepare the student to comprehend with ease the principles and details of all methods not explained in it. The compiler had wished to introduce the constructions of Coëhorn, but to do so with clear plans and descriptions, would have increased the bulk beyond its original limits. For an acquaintance with these systems, the pupil is referred to the works of Coëhorn; or of Bousmard.

Coëhorn was the Vauban of Holland; he excelled in constructing works (more especially in the aquatic ground of his native country): as well as in the art of attack.

His services and talents have gained him a great and deserved reputation. His methods have been applied with suitable modifications to localities, at Nimeguen, Breda, Manheim, Namur, and Bergen-op-Zoom. The French experienced at the siege of this last place how much the genius of Coëhorn could influence the defence, against an attack, conducted with as much science as valour. He formed various great retrenchments as those of Svool and Groninguen. He attacked with great success Bonn, Boulinbourg, Traenback, Limbourg, the citadel of Liege, and the castle of Namur, in 1695; he had also defended this last place in 1692 against the attacks of Vauban, who greatly respected and honoured his talents.

A description of Chasseloup de Laubat's system of fortification, as executed at Alessandria, has just been published (1833) by an officer of the corps of Royal Engineers, accompanied by three beautifully executed plates, illustrative of the interesting and formidable construction that received the full approbation of Napoleon. This work contains most useful matter for the study of intelligent cadets, after passing through the usual details, such as given in this volume.*

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* "Description of Chasseloup de Laubat's System of Fortification, as executed at Alessandria. By an officer of the corps of royal engineers. London: James Fraser, 215, Regent Street.—1833."

APPENDIX.

ON THE PRESSURE OF EARTH AGAINST REVÊTEMENT WALLS.

In the last chapter of an elementary treatise on fortification, by Colonel Pasley of the Royal Engineers, the nature of the pressure of earth against revêtement walls is investigated. The force and truth of some of his remarks, as well as his declaration that none of the solutions, hitherto given, were satisfactory, have led to the following endeavour to put this interesting subject in a more favourable light, on principles strictly mathematical, the result of which most closely agrees with a series of experiments made at Addiscombe, and yet more with the extensive practice of the celebrated Marshal Vauban; the masonry of whose numerous and able constructions have stood the test of time.

PROBLEM.

To determine the force with which a bank of earth presses against a wall or revêtement; and the requisite dimensions of the wall or revêtement necessary to support it.

Plate 15: Let (*ABCDEFG*), fig. 1, be a vertical section of the bank of earth; of which bank, were it not supported by the wall or revêtement (*EDLF*), the part (*BCDEF*) would fall or slide down, leaving the remainder (*FGAB*) standing at what is termed the natural slope (*BF*); let the sine and cosine

of the angle which this line (BF) makes with (GF) be represented by (s) and (s'), the radius being unity: through (I) the centre of gravity of the figure ($BCDEF$), draw (IH) parallel to (BF) the natural slope; also draw (DEK) parallel to (GF), the line (EF) being perpendicular to (GF), and equal to the height of the wall or revêtement. Now the centre of gravity (I) of the figure ($BCDEF$) may be accounted its place, into which its mass is all collected; the force, therefore, with which it endeavours to descend in the direction (IH) parallel to (BF), will be expressed by the weight of the mass ($BCDEF$) multiplied by $\frac{EF}{KF}$ or by (s) the sine of the angle (BFG). See Hutton's Mathematics, vol. ii.—Inclined Plane. Put the specific gravity of earth equal to (m), the area of the figure ($BCDEF$) equal to (a), then its weight will be (am), and its force or pressure in the direction (IH) will be $\left(am \times \frac{EF}{KF}\right)$ or (ams). With this force the mass or matter in ($BCDEF$) presses or acts obliquely upon the face of the wall or revêtement (EF) at (H); and being resolved (see second volume of Hutton.—Resolution of Forces) gives ($amss'$) for the force acting at (H) perpendicular to (EF); and (ams^2) for the force acting at (H) parallel to (EF). Here, then, are two forces; the first, acting perpendicularly at (H) the extremity of the lever (HF), has a direct tendency to overturn the wall or revêtement; whilst the second, acting perpendicularly at (F) the extremity of the lever (FL), has a tendency to give stability to the wall or revêtement by counteracting the effect of the first force: it is, therefore, evident that it is the difference of the effects of these forces that must be balanced by the counteraction of the wall or revêtement; viz.—($amss' \times HF - ams^2 \times FL$). Now let ($O$) be the centre of gravity of the wall or revêtement, draw (OP) perpendicular to (FL); put the area ($DEFL$) equal to (w), and its specific gravity equal to (n); then will (nw) be the weight of the wall or revêtement: the efficacy of this weight, acting at (P), the extremity of the lever (PL), will be equal to ($nw\times PL$), and this must be equal to the effect of the mass of earth, in order that it may just support it; and which was before found equal to ($amss'\times FH - ams^2\times FL$); consequently,

$$nw\times PL = amss'\times FH - ams^2\times FL$$

which equation is general, and is deduced from principles which are unquestionable.

It may, however, be still more satisfactory to show, that the same general result can be obtained by following a different mode of solution; and thus verifying the truth of the principles upon which both solutions are founded. In the figure before referred to, from (H) draw (JH) perpendicular to (BF); draw also (TR) through (L), parallel to (JH) or (IN), and meeting (IH) and (NJ) respectively in (R) and (T); then,

$$JH = FH\times s' = TR$$

$$TL = FL\times s$$

$$\text{therefore } LR = FH\times s' - FL\times s.$$

But it has been found in the former solution, that the force of the mass ($BCDEF$), in the direction (IH), is equal to (ams); and as this force acts perpendicularly at (R), the extremity of the lever LR, its efficacy, or power to overturn the wall or revêtement, will be expressed by ($ams\times LR$), equal to (ams) $\times$ ($FH\times s' - FL\times s$); and the force arising from the counter resistance of the wall or revêtement is equal to ($nw\times PL$), consequently

$$nw\times PL = ams\times (FH\times s' - FL\times s)$$

$$\text{or } nw\times PL = amss'\times FH - ams^2\times FL$$

the same as the general equation which was found before; and which shows clearly, that the force which acts parallel to (EF), and was found in the former solution to be equal to ams^2, ought not to to be neglected.

When (R) coincides with (L), that is, when the line of direction of the force passing through the centre of gravity, passes also through L, the extremity of the base of the wall or revêtement, the stabilitating force becomes equal to the force which tends to overturn: that is,

$$amss'\times FH = ams^2\times FL.$$

This result may be verified by a very simple experiment, as follows; place a rectangular board ($ABCD$), fig. 2, of any length and breadth, perpendicularly upon an horizontal plane, (ZM); let the extremity (A) be secured so as to prevent its sliding along (ZM), but not so as to prevent its turning freely about (A) as a pivot; draw the diagonal (AC), and produce it to (L). Then if any force, however great its power, be applied at (C) in the direction (AL), the rectangle will remain immoveable; but if the direction of the force be changed, so that the angle (LCB) become greater than the angle (CAB), the force applied will immediately overturn the rectangle ($ABCD$).

In fig. 3, which represents a vertical section of a full sloping revêtement,

let a'=area of ($BCPDEF$).

p=perpendicular distance of the centre of gravity of the triangle FEK from DP.

w=area of the triangle (FEK).

p'=perpendicular distance of the centre of gravity of the parallelogram ($DKAS$) from DP.

w'=area of the parallelogram $DKAS$.

p''=perpendicular distance of the centre of gravity of the quadrangle ($BCPS$) from DP

w''=area of the quadrangle ($BCPS$)

s=sine of 45°, the natural slope

s'=cosine of 45°.

b=DS.

a=altitude of the wall or revêtement.

x=breadth of the wall or revêtement at the top.

ra=slope of the wall.

n=specific gravity of the wall.

m=specific gravity of the earth.

d=resistance arising from the cohesion of the earth in sliding down the inclined plane, and which has been found by experiment to be equal to $\frac{1}{3}$ nearly. See Hutton's Course, vol. 3, page 257.

$$\frac{n}{dms}=g$$

Then (IZ) the distance of the centre of gravity of the mass $(DPCBAF)$ from (DP) is equal to $\frac{pw+p'w'+p''w''}{w+w'+w''}$ See the above course, vol. 2, page 169.

$$\text{But, } p=\frac{2as}{3}+sx$$

$$w=\frac{a^2}{2}$$

$$p'=s\left(\frac{a+x}{2}\right)$$

$$w'=bs(a+x)$$

$$\text{therefore } IZ=\frac{as^3+\frac{a^2sx}{2}+\frac{bs^2(a+x)^2}{2}+p''w'}{\frac{a^2}{2}+bs\ (a+x)+w''}$$

$$\text{and } ZN=s(a+x)$$

$$ZN-IZ=IN=s(a+x)-\frac{as^3+\frac{a^2sx}{2}+\frac{bs^2(a+x)^2}{2}+p''w'}{\frac{a^2}{2}+bs(a+x)+w''}$$

$$=\frac{\frac{bs^2}{2}(a+x)^2+sw''(a+x)+\frac{sa^3}{6}-p''w'}{\frac{a^2}{2}+sb(a+x)+w''}$$ the perpendicular distance of the centre of gravity of the mass $(DCPBAFE)$ from (AF) the natural slope, also the distance of the centre of gravity LP of the revêtement $(DEFL)$ is found in the same manner to be equal to

$\frac{\frac{2}{3}ra\times\frac{ra^2}{3}+\left(ra+\frac{x}{2}\right)\times ax}{w}$, because $\frac{2}{3}ra$ is the distance of the centre of gravity of the triangle (LRD) from (L); and $\left(ra+\frac{x}{2}\right)$ is the distance of the centre of gravity of the parallelogram $(DEFR)$, from (L) also; and (LF) equals $ra+x$: if, therefore, the respective values of (PL), (IN), and (LF) be substituted, the general equation

$$nw \times PL = a'mss' \times FH - a'ms^2 \times FL$$
$$= a'ms \times IN - a'ms^2 \times FL$$

$$\frac{nw}{ms} \times PL = a' \times IN - a's \times FL \text{——becomes}$$

$$g\frac{r^2a^3}{3} + \left(ra+\frac{x}{2}\right) \times agx = \frac{(a+x)^2}{2} \times bs^2 + sw''(a+x) + \frac{sa^3}{6}$$
$$\overline{-p''w'' - s(ra+x) \times \frac{a^2}{2} + sb(a+x+w'')}$$

$$\text{hence } x^2 + \left(\frac{2bs^2ra+2gra^2+sa^2}{bs^2+ga}\right)x$$

$$= \frac{(sa-sra-p) \times 6w'' + (1-2r)3bs^2a^2 + (1-3r)a^3s - 2r^2a^3g}{3(bs^2+ga)}$$

$$\text{and } x = \left(\frac{(sa-sra-p)6w'' + (1-2r)3bs^2a^2 + (1-3r)a^3s - 2r^2a^3g}{3(bs^2+ga)}\right.$$
$$\left. + \overline{\frac{2bs^2ra+2gra^2+sa^2}{2(bs^2+ya)}\Big|^2}\right)^{\frac{1}{2}} - \frac{2b^2ra+2gra^2+sa^2}{2(bs^2+ga)} \text{ the}$$

breadth of the wall at the top of the revêtement. From this value of x the dimensions of all the revêtement walls in Vauban's profile may be determined, see figs. 4, 5, and 6.

When r equals zero, the revêtement walls become rectangular, as in figs. 7, 8, and 9.

$$\text{and } x = \sqrt{\frac{(sa-p'')6w'' + 3bs^2a^2 + a^3s}{3(bs^2+ga)} + \left(\frac{sa^2}{2(bs^2+ga)}\right)^2}$$
$$-\frac{sa^2}{2(bs^2+ga)}$$

If b, p'' and w'' each equal zero, then

$$x = \sqrt{\frac{(1-3r)a^2s - 2r^2a^2g}{3g} + \left(\frac{2gra+sa}{2g}\right)^2} - \frac{2gra+sa}{2g}$$

which gives the breadth at the top of the counterscarp sloping revêtement, fig. 10; but when (b) (p'') (w'') and (r) each becomes equal to zero, then

$$x=\sqrt{\frac{a^2 s}{3g}+\left(\frac{sa}{2g}\right)^2}-\frac{sa}{2g}$$

which determines the dimensions of the rectangular counterscarp revêtement, fig. 11.

It appears, therefore, that from the general value of x, the dimensions of all the revêtement walls, constructed by Vauban in his System of Fortification can be determined; the demi-revêtement with a berm being the only exception: but in order to compare these theoretical results with the practice of Vauban, recourse must be had to numbers. These numbers were obtained from Captain Straith, and from them the different values of the known literal quantities used in the equation, are as follows:

$a=30$ feet

$b=6\sqrt{2}$

$r=\frac{1}{5}$

$d=\frac{2}{3}$

$w''=135\cdot5$

$p''=\ 7\cdot712$

$p''w''=1044\cdot976$

$m=1900$

$n=2000$

$s=\frac{1}{\sqrt{2}}$ sine of 45°

$\frac{n}{dms}=g=\frac{20\times3\times\sqrt{2}}{2\times19}$

If these numbers be substituted in the equation

$$x=\left(\frac{(sa-sra-p'')6w''+(1-2r)3bs^2a^2+(1-3r)a^3s-2r^2a^3g}{3(bs^2+ga)}+\frac{2bs^2ra+2gra^2+sa^2}{2(bs^2+ga)}\Big)^2\right)^{\frac{1}{2}}-\frac{2bs^2ra+2gra^2+sa^2}{2(bs^2+ga}$$

the value of x will be found equal to 3·5 feet. Therefore 9·5 feet is the breadth of the full scarp sloping revêtement.

If $b=3\sqrt{2}$ the other numbers remaining the same as before, the value of x will be 2·77. The breadth of the revêtement in this case is 8·77 feet.

In the demi-revêtement $a=15$ feet and $b=21\sqrt{2}$ the other numbers being the same x becomes equal to 3·7 feet. Its breadth is therefore equal to 6·7 feet.

Vauban's dimensions for these three revêtements are, for the two first, each 11·3 feet, and for the last 8·4 feet. It may be as well to observe here, that the theoretical results are barely sufficient to support the pressure of the earth; some addition to the breadth of the revêtements must, therefore, be made in order to insure the requisite stability. If 1·5 feet be allowed for this purpose, the three revêtements determined by theory, will then agree very closely with those of Vauban.

If the breadth of each of Vauban's three revêtements be compared with its height, it will be found to be greater than one third of the height; consequently, a line drawn through the centre of gravity of the triangle, parallel to the natural slope, will pass through the base of the revêtement, therefore the pressure of the triangle increases the stability.

For the counterscarp sloping revêtement,

$a=22$ $\qquad$ $d=\frac{2}{3}$

$r=\frac{1}{5}$ $\qquad$ $s=\frac{1}{\sqrt{2}}$ sine of 45°

$m=1900$

$n=2000$ $\qquad$ $\frac{n}{dms}=g=\frac{20\times3\sqrt{2}}{19\times2}$

these values being substituted in the equation.

$$x=\sqrt{\frac{(1-3r)a^2s-2r^2a^2g}{3g}+\left(\frac{2gra+sa}{2g}\right)^2}-\frac{2gra+sa}{2g}$$

give ·46 for the breadth of the top of the revêtement: its thickness is therefore equal to 4·86 feet; Vauban's revêtement is 9·73 feet, which is greater than the theoretical revêtement by 4·69 feet. This difference is certainly great: but it must be borne in mind, that the terre-pleine of the counterscarp revêtement is used as a road for the passing of troops, stores, and cannon, &c. These, by their weight, add considerably to the pressure of the earth, and this increase of pressure must be met or counteracted by a corresponding increase to the thickness of the revêtement.

In fig. 12, which represents the counterscarp revêtement, draw (CF) parallel to the natural slope; then (AD) being 22 feet, and (CD) 9·73 feet, (BF) will be 17·5 feet. Now the weight of an 18-pounder iron gun, with its travelling carriage, is about three tons; and if, in passing along the terre-pleine, its road should be between B and F, (and there is ample space for it), its weight would add considerably to the pressure against the wall; because a line PG drawn through the centre of gravity of the gun, parallel to the natural slope, would fall without the base (CD) of the revêtement; and the effect of this pressure would be proportional to the weight of the gun, multiplied by the lever CG; that is, if CG equal ten feet, to a weight of thirty tons.

In the full scarp revêtement, if the line CD be drawn parallel to the natural slope, it will, when produced, pass through the lower extremity of the interior slope of the parapet, or within one foot of it; fig. 13. Hence it follows that if a gun be placed on its platform ($m\,n$), the line of direction of its pressure will fall within CB; and its weight will add stability to the revêtement. No addition, therefore, to its thickness is requisite.

In the demi-revêtement with a berm, (fig. 14.) if the line of the natural slope be produced, it will in this case pass through the superior slope of the parapet. And as the altitude of the revêtement, and the breadth of the berm, are given, the distance of the centre of gravity of the mass ($FCDEN$) from the natural slope, as also its area, are known. Through (I) the centre of gravity of $FCDEN$, draw IR parallel to FN, the natural slope; and through L, RO perpendicular to FN meeting (FN) and (IR) in O and R.

Let a=altitude of the revêtement.

$r\,a$=its slope.

x=breadth of the top of the revêtement.

n=specific gravity of brick.

m=specific gravity of earth.

d=resistance arising from the cohesion of the earth in sliding down the inclined plane.

p=perpendicular distance of the centre of gravity of $ICDEN$ from IN.

b=area of $FCDEN$.

$g=\frac{n}{dms}$

$s=\frac{1}{\sqrt{2}}=$ sine of 45°

Then $LO=s(ra+x)$, and $RO=p$.

Therefore $p-s(ra+x)=p-sra-sx=RL$;

and by substituting in the general equation

$$\frac{nw}{mds}\times PL=b\times RO-bs\times FL.$$

$$\frac{mw}{mds}\times PL=bp-bsra-bsx.$$

$$\text{but } w\times PL=\frac{r^2a^3}{3}+\left(ra+\frac{x}{2}\right)ax \text{ and } g=\frac{n}{mds}$$

$$\frac{gr^2a^3}{3}+gra^2x+\frac{gax^2}{2}=bp-bsra-bsx$$

$$\text{from which } x=\sqrt{\frac{6b(p-sra)-2gr^2a^3}{3ga}+\left(\frac{gra^2+bs}{ga}\right)^2}-\frac{gra^2+bs}{ga}$$

which determines the dimensions of the demi-revêtement with a berm.

It is to be regretted that this result cannot be compared with the practice of Vauban, because there is no profile of this demi-revêtement, with a berm, to be met with in any of the numerous writers on the subject of fortification. Had such been the case there can be no doubt but that the comparison would have been favourable to the theory.

In conclusion, it may be as well to give here the results of a few practical experiments made at Addiscombe, in order to ascertain how near the theory would agree with practice. Having, therefore, contrived a model for this purpose, and upon application to Sir Alexander Dickson, the public examiner, and Colonel R. Houstoun, the lieutenant governor of the military seminary, obtained their sanction for its construction; the experiments hereafter detailed were made, and found to agree in the most satisfactory manner, with the theoretical results.

The model was constructed in this way: two upright sides (see fig. 15) each thirty inches high, were securely fastened to a board or plank twelve inches wide, and six feet in length; a plank of the same breadth as the bottom was then fixed, within ten inches of the end *A* of the bottom of the model, making with it an angle of 45°, and, being secured, preserved the sides in a vertical position: two upright posts were attached to the sides, connected at the top by a cross beam, in which a pulley was fixed; at the end *A C*, a door was fitted, so as to turn about (*C*) and (*A*) as pivots; its height was equal to the height of the sides, and it could be removed at pleasure: near the bottom of the door was a ring, to which was fastened one end of a line, which line, after passing over the pulley, had a weight attached to it; and this weight held the door in close contact with the end of the model: narrow strips of leather were glued to the ends (*AE*) and (*F C*), and round the face of the door; and by this contrivance, the contact was so perfect, that not a single particle of sand could escape. The method of using the model is as follows (see fig. 16): take the angle of the natural slope with a bevil, then place one limb of the bevil vertically against the upright end of the model (*A B*), and by means of the shifting lever *G G*, (which is simply a rod 22 inches in length), raise or depress the line (*G P*), until it is parallel to the other limb of the bevil. This done, fill the model with sand or earth, and adjust the weights (*w*) at the end of the line, so as just to counterbalance the pressure of the sand or earth against the moveable upright end. Measure the perpendicular distance of the line, from the natural slope of the sand or earth, and multiply this distance by the weight attached to the line: measure also the greatest perpendicular distance of the top of the sand, from the natural slope, and divide the above product by one third of this last distance, and the quotient will be equal to the force or weight, with which the sand presses against the end or door. The reason for this will appear evident by inspecting the fig. 16, in which (*A B C D*) represents a vertical section of the model.

A C the natural slope.
A B the moveable end or door.
G G the shifting lever.
G P the line parallel to *A C*.
w the weight.

Let (mn) be drawn perpendicular to (AC), through (B), meeting (AC) and (GP), in (n) and (m), and through (I) the centre of gravity of the triangle (ABC), draw (roI) parallel to (AC), meeting (mn) and (AB) in (o) and (r). Then by the property of the lever $w \times mn$ equals $on \times$ by the force or pressure of the triangle (ABC) in the direction (roI). Call this force or pressure (f), and let the sine and cosine of the natural slope be expressed by (s) and (s'). Now to determine the requisite thickness of the revêtement, to withstand this force or pressure, let $KB = x$, $AB = a$, and $RL = b$, then by substituting, the general equation becomes

$$s'f \times \frac{a}{3} = sf(b+x) + ax\left(b+\frac{x}{2}\right) + \frac{ab}{2} \times \frac{2b}{3}$$

therefore $x = \sqrt{\frac{2s'f - 2b^2}{3} - \frac{2sfb}{a} + \left(\frac{sf+ab}{a}\right)^2} - \frac{sf+ab}{a}$

The model being charged with sand, and the force (f) ascertained by experiment, the value of x was found equal to 2·7 inches nearly; and the thickness of the revêtement 8·7 inches. But if the value of (f) be found by the theory, x will be 2·79 inches, and the thickness of the revetement 8·79 inches. When the model was charged with shingle, and the value of (f) carefully ascertained by experiment, x became equal to 3 inches; and the breadth of the revêtement 9 inches; but when (f) was found by the theory, x equalled 3·46 inches, and the breadth of the revêtement 9·46 inches.

A case of thin wood was made similar to a revetement: its height, 30 inches; breadth at top, 2·79 inches; breadth at bottom, 8·79 inches: these being the dimensions found by theory. The door of the model was then removed, and the face of the revêtement placed in close contact with the end of the model, and secured at the bottom, to prevent its sliding. Then both the revêtement and model being filled with sand, the revêtement was found barely sufficient to withstand the pressure of the sand in the model.

In making these experiments, it is of the first importance, that the sand or shingle be perfectly dry; it being found by repeated trials, that the angle of the slope varies, and the slope itself becomes irregular, in proportion to the dampness of the sand or shingle; but, when perfectly dry, the slope is even, and its angle constant.

FINIS.

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